Volume 21 DECEMBER, 1937 Number 12

BULLETIN
of the
American Association *of* Petroleum Geologists

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BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OFFICE OF PUBLICATION, 608 WRIGHT BUILDING, TULSA, OKLAHOMA

THE BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS is published by the Association on the 15th of each month. Editorial and publication office, 608 Wright Building, Tulsa, Oklahoma, Post Office Box 979, Cable address, AAPGEOL.

THE SUBSCRIPTION PRICE to non-members of the Association is $15.00 per year (separate numbers $1.50) prepaid to addresses in the United States. For addresses outside the United States, an additional charge of $0.40 is made on each subscription to cover extra wrapping and handling.

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BOX 979
TULSA, OKLAHOMA

Entered as second-class matter at the Post Office of Tulsa, Oklahoma, and at the Post Office at Menasha, Wisconsin, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1923.

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(Organized at Tulsa, Oklahoma, February 10, 1917, as the Southwestern Association of Petroleum Geologists. Present name adopted, February 16, 1918. Incorporated in Colorado, April 23, 1924. Domesticated in Oklahoma, February 9, 1925.)

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Volume 21 Number 12

BULLETIN
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AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

DECEMBER, 1937

STRATIGRAPHY OF THE PERMIAN IN OKLAHOMA AND KANSAS

EDITOR'S NOTE

The following discussions on the stratigraphy of a portion of the Permian Red-Beds in Oklahoma were contributed to a conference held in Norman, on May 8, 1937, sponsored by the University of Oklahoma chapter of Sigma Gamma Epsilon, honorary geological fraternity, on the occasion of the annual meeting, and planned and arranged by the Oklahoma Geological Survey. Charles N. Gould acted as chairman.

The program follows.

"Permian Sediments Exposed in West-Central Oklahoma," by Darsie A. Green

"Relation of Marlow to Dog Creek-Blaine and Duncan-Chickasha Formations," by Otto E. Brown

"Quartermaster Unconformity of the Weatherford Area," by Noel Evans

"Permian Correlations above the Garber Sandstone," by Henry Schweer

"The Lower Red-Beds of Kansas," by George H. Norton

These papers were followed by general discussion from the floor. Notes were taken by J. O. Beach, secretary of the Oklahoma Geological Survey, and later submitted to all who participated, for corrections and additions.

This conference elicited many divergent opinions, presented many new data, and brought together so much up-to-date information on the Permian of Oklahoma, that it seems desirable to present it here in one issue of the *Bulletin*.

Green's material was previously presented in his recent paper[1]

[1] Darsie A. Green, "Permian and Pennsylvanian Sediments Exposed in Central and West-Central Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 11 (November, 1936), pp. 1454–75.

and this was taken as the theme of the conference. Brown had already prepared his paper "Unconformity at the Base of the Marlow," for offering to the *Bulletin*.

Green has since prepared a supplement to his first paper, and it, and Brown's, together with discussion of the latter by Henry Schweer and Hastings Moore appear on following pages. The papers by Evans and Norton are printed here as they were presented at the conference and Schweer's cross section is reproduced. Most of the discussion from the floor has been corrected and amplified by those who took part.

The reader who is interested in tracing the development of the knowledge of Permian stratigraphy in Oklahoma during recent years is referred to the bibliography on page 1573.

It is evident from the discussions that decided differences of opinion exist about the importance of lateral gradation in the Blaine and Duncan-Chickasha formations, and about the magnitude of unconformity at the base of the Marlow formation. These questions can be settled only in the field, and it is to be hoped that a conference can be arranged for the purpose of reconciling the divergent views in a final solution of the problem.

ROBERT H. DOTT, *director*
Oklahoma Geological Survey

NORMAN, OKLAHOMA
September, 1937

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 12 (DECEMBER, 1937), PP. 1515-1533, 5 FIGS.

MAJOR DIVISIONS OF PERMIAN IN OKLAHOMA AND SOUTHERN KANSAS[1]

DARSIE A. GREEN[2]
Tulsa, Oklahoma

ABSTRACT

This extension to a former paper shows some major time lines which are used to divide the Permian of Oklahoma into three divisions. The section starts at the top of the Brownville limestone and extends upward to the Tertiary overlap above the Elk City sandstone. The three time divisions are shown graphically. Some reference is made to the geologic history which may be interpreted from the gradations in the clastic units. Local formations are not considered to have correlative equivalents in far distant localities. A correction is made concerning the writer's previous classification of the Cloud Chief formation. Whitehorse and Quartermaster are used as group names.

The writer's talk presented at the conference sponsored by the Sigma Gamma Epsilon, at Norman, May 8, 1937, was based largely on a previously published paper,[3] consequently was not intended for publication. At the request of Robert H. Dott, director of the Oklahoma Geological Survey, this partial summary of the Norman talk is presented as an extension to the former paper. Some new material is used and some revision in the classification of the sediments above the base of the Marlow formation is made.

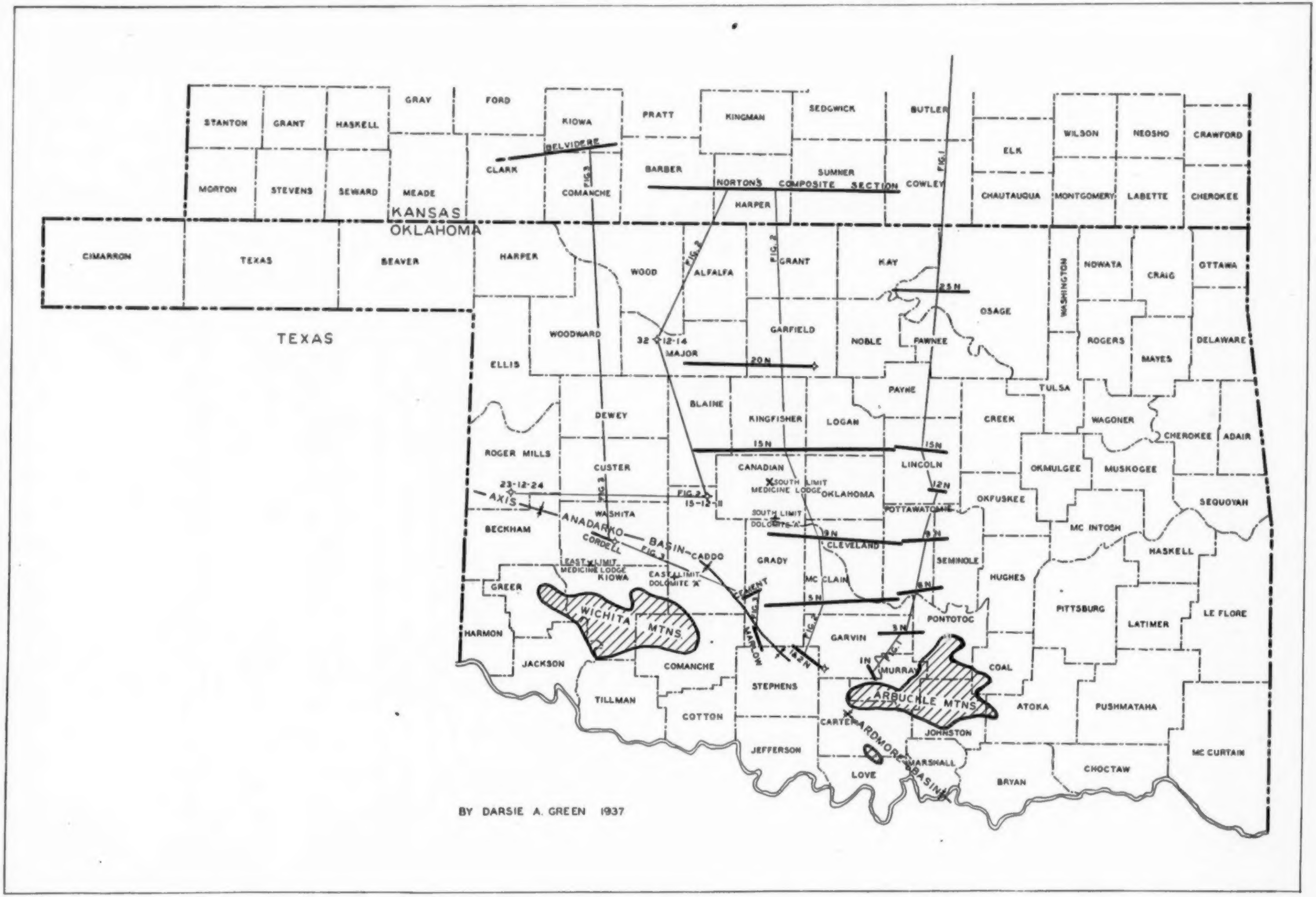
There are some major lines in Oklahoma and Kansas which may be used to divide Permian sediments into natural time divisions. For the convenience of the reader these divisions and time lines are shown graphically in Figures 1, 2, and 3. For the further convenience of reference, these divisions are given names which may prove to be useful only in the area under consideration. In addition to showing the nature, position, and distribution of these gradational sediments, some suggestions will be made concerning the geologic history which caused the gradations and variable thicknesses. The Index map shows the geographic locations of the sections included in Figures 1, 2, and 3.

In this work, use has been made of all the detailed mapping by the numerous Pure Oil Company geologists with whom the writer

[1] Manuscript received, July 6, 1937. Published by permission of the chief geologist of The Pure Oil Company.

[2] Box 271.

[3] Darsie A. Green, "Permian and Pennsylvanian Sediments in Central and West-Central Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 11 (November, 1936), pp. 1454-75.



Index map showing geographic location of sections used in Figures 1, 2, and 3. Notice south and east limits of Medicine Lodge gypsum and Dolomite "A," Canadian, Caddo, and Washita counties.

has been associated during the past 14 years. The subsurface interpretations are largely by Ira H. Cram, to whom the writer is indebted for many helpful suggestions which have been incorporated both here and in the former paper.

The area to be considered extends from the Arbuckle and Wichita mountains northward into Kansas. In this northern Permian basin the sediments are lenticular and gradational, but when compared with the southern Permian basin, recently described by Walter B. Lang,[4] the stratigraphy is relatively simple and the sediments are relatively thin. Unfortunately no author has shown a familiarity with the details of the sediments in both north and south Permian basins, yet many have attempted to make correlations from one basin to the other. Each basin had its separate geologic history and consequently separate sedimentary units. Each basin has different sedimentary facies at different localities within the one basin. For these reasons it appears fallacious to correlate a local group of formations found in one basin with any local group of formations of similar lithology which may occur in a restricted area within the other basin. Since this writer's work has been limited to the northern basin, no correlations are attempted with sediments in the southern basin. The major divisions in Oklahoma and Kansas, with their time boundary lines, are here presented with the thought that it may be possible to find correlative time lines in other regions which may prove helpful in making regional correlations.

In southern Kansas and northern Oklahoma many horizons within the upper marine section have been suggested for the basal Permian contact, the tendency being toward lowering the contact in each new publication. The 1934 "Composite Section" by the Kansas Geological Survey established the contact at the top of the Brownville limestone or at the base of the Indian Cave sandstone where the Indian Cave is present. This contact is somewhat questionably incorporated in the "New Geologic Map of Kansas, 1937." Raymond C. Moore, director of the Kansas Geological Survey, speaking before the Tulsa Geological Society, April 5, 1937, explained that the base of the Permian system can not be definitely established in America until it is established at the type locality in Europe. There is also some question concerning the upper boundary of the Permian. Robert Roth[5] would include the sediments above the base of the Whitehorse

[4] Walter B. Lang, "The Permian Formations of the Pecos Valley of New Mexico and Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 7 (July, 1937), pp. 833–98.

[5] Robert Roth, "Evidence Indicating the Limits of Triassic in Kansas, Oklahoma, and Texas," *Jour. Geol.*, Vol. 40, No. 8 (November–December, 1932).

group in Kansas and northwestern Oklahoma in his revised Triassic.

Until there is more agreement concerning the age of these sediments, it seems advisable to consider all the sediments shown in Figures 1, 2, and 3 as Permian. If a new boundary line is established for any system, it is probable that it will coincide with one of the major time lines here defined.

Within the major divisions some of the more commonly referred to Oklahoma formations are shown at the type localities. The sections show the difficulty encountered when far distant correlations were made with these type localities. The early workers could correlate only by similarity of lithology and sequence. This resulted in numerous errors which have been detected by continuous detailed structural mapping. There are many local formations that have been found useful for structural mapping which have never been described in the literature, and there are descriptions in the literature of local formations which can not be identified 10 miles away from the type locality. It is most unfortunate that such local units, which have no correlative value in adjoining counties in Oklahoma, have been extensively used in the regional correlation charts in the literature of other states. In this article such local units will be ignored except for showing what and where some of them are.

Since the three major divisions are time units rather than lithologic units, there are no type localities. The names used for references are as follows.

Wanette; from the town of Wanette which is located in southwestern Pottawatomie County, Oklahoma

Minco; from the town of Minco which is located in northern Grady County, Oklahoma

Upper Red-Beds; a descriptive name which includes the sediments from the base of the Marlow formation to the Tertiary overlap above the Elk City sandstone

At the Norman conference an attempt was made to use Roth's term "Custer" in connection with the last mentioned division, but further study has shown that the "Custer" as defined in Oklahoma can not be accepted as either a stratigraphic or a time unit. This will be clarified in the discussion of the upper Red-Beds division.

WANETTE DIVISION

In central Oklahoma the Wanette division includes the sediments from the top of the Brownville limestone to the top of the Stratford shale, which is the top of the Pontotoc terrane. In the former paper the top of the Stratford shale was shown to be the time equivalent of the top of the Herington limestone of the northern marine section. The sections show that the identification of the Brownville

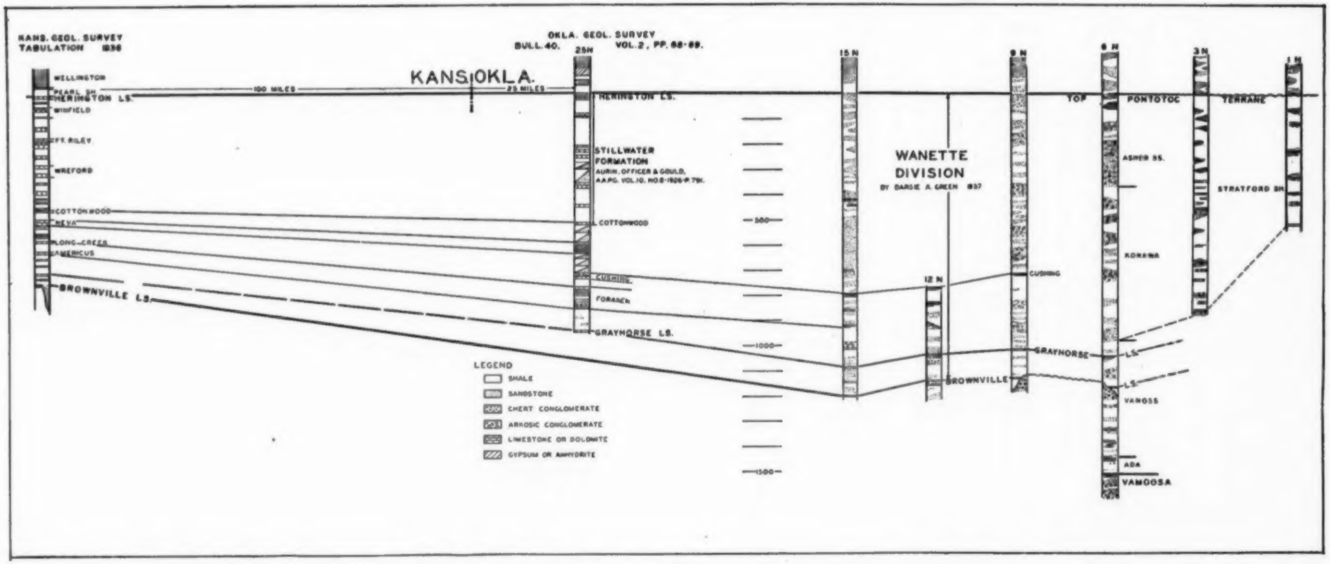


FIG. 1.—Graphic section showing "Wanette" time division of Permian sediments. For geographic locations, see Index map.

limestone in the southern area is based on a correlation of the published sections for Kansas and for northern Oklahoma, a correlation so well tied that it can not be seriously questioned.

In the southern area the Brownville occurs in the upper part of Morgan's Vanoss formation[6] of the Pontotoc terrane. Through Seminole County this limestone is unconformable with masses of Pennsylvanian sandstone-chert conglomerates which in many places protrude 25 feet above the plane of the limestone, thus showing that the erosion preceded the deposition of the limestone. In Kansas the unconformity, along which the basal contact of the Permian system is now placed, has been given a different history from that found in Seminole County. The Kansas section shows that the erosion was post-Brownville and that it cut channels far below the normal plane of the limestone, the channels being later filled by the Indian Cave sandstone of Permian age. This difference in interpretation concerning the unconformity in no way alters the correlation of the limestone.

Attention is directed to the position of the Stillwater formation in T. 25 N. and to the gradations which make it impossible to find a lower boundary for this formation in the southern area. The Stillwater is the basal member of Aurin, Officer, and Gould's Enid group.[7] The top of this Enid group is at the base of the Blaine gypsum in Kansas and northern Oklahoma. The 1926 classification made the Enid group include 1,300 feet of sediments which are below the base of the Enid formation as originally described by Gould.[8] This new classification definitely dropped the term Enid as a formation name.[9] The Kansas Geological Survey has not accepted Gould's withdrawal of his term Enid formation and the new "Geologic Map of Kansas" uses the Enid as originally defined. Future references to the Enid should be made with careful qualifications.

Gradations within the Wanette division make it impossible to trace northern formation boundary lines through central Oklahoma, and record the history of a shore line on the east which was lifted by stages and progressively moved westward. Each uplift caused the delta in front of this shore line to extend farther westward than the next older deltaic sediments, and each uplift caused shoreward erosion which resulted in a local unconformity. These unconformities

[6] George D. Morgan, "Geology of Stonewall Quadrangle," *Bur. of Geol. Bull.* 2 (1924), Norman, Oklahoma.

[7] F. L. Aurin, H. G. Officer, and Charles N. Gould, "The Subdivisions of the Enid Formation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 8 (August, 1926), p. 791.

[8] *Ibid.*, p. 786.

[9] *Ibid.*, p. 792.

shortened the shoreward sections. On the south the Arbuckle Mountains were also being uplifted by stages, but, on account of the small area and the absence of large rivers, the Arbuckle sediments were not carried far from shore. The materials from the Arbuckles were primarily arkose, limestone, and chert.

The Wanette sediments now exposed in Oklahoma may well be described as being predominantly deltaic in the central area, marine on the north, and semimarine on the south. In the subsurface of western Oklahoma the Wanette division is like the northern section, which shows that the central delta did not extend to the western area during Wanette time. In the area immediately north of the Wichita Mountains the Wanette is overlapped by Minco sediments and is not exposed. Underground in this area the division is quite similar to the outcrops exposed just north of the Arbuckles. In subsurface the top of the Wanette is used for mapping, but the base is not easy to identify.

MINCO DIVISION

The Minco division extends from the top of the Herington limestone, or the top of the Stratford shale, to the base of the Marlow formation. The basal boundary line represents a very definite change in environment, except in a few counties in central Oklahoma where the delta from the east continued to build from Wanette time on into Minco time. That part of these central deltaic sediments which was deposited during early Minco time may conveniently be called the Garber delta. In the subsurface the top of the Herington may be identified directly under the westward tongues of the higher Garber delta sandstones.

The upper contact of the Minco is very sharp at the surface from southeastern Kiowa County, Kansas, southward across Oklahoma to the head of the Anadarko basin in southeastern Grady and northern Stephens counties, and then northwestward along the south side of the Anadarko basin into southeastern Beckham County, a distance of approximately 300 miles. The upper limit of the Minco is difficult to find in subsurface work except in wells from which samples are available.

The top of the Enid group as defined by Aurin, Officer, and Gould is at the base of the Blaine gypsum in the northern area and at the base of the Marlow formation in Grady County, where the Marlow was long miscorrelated with the Blaine. Thus the upper limit of the Minco is shown to be above the Enid boundary over the greater part of the area. As previously stated, the Enid group included the Stillwater formation, which is below the Minco division.

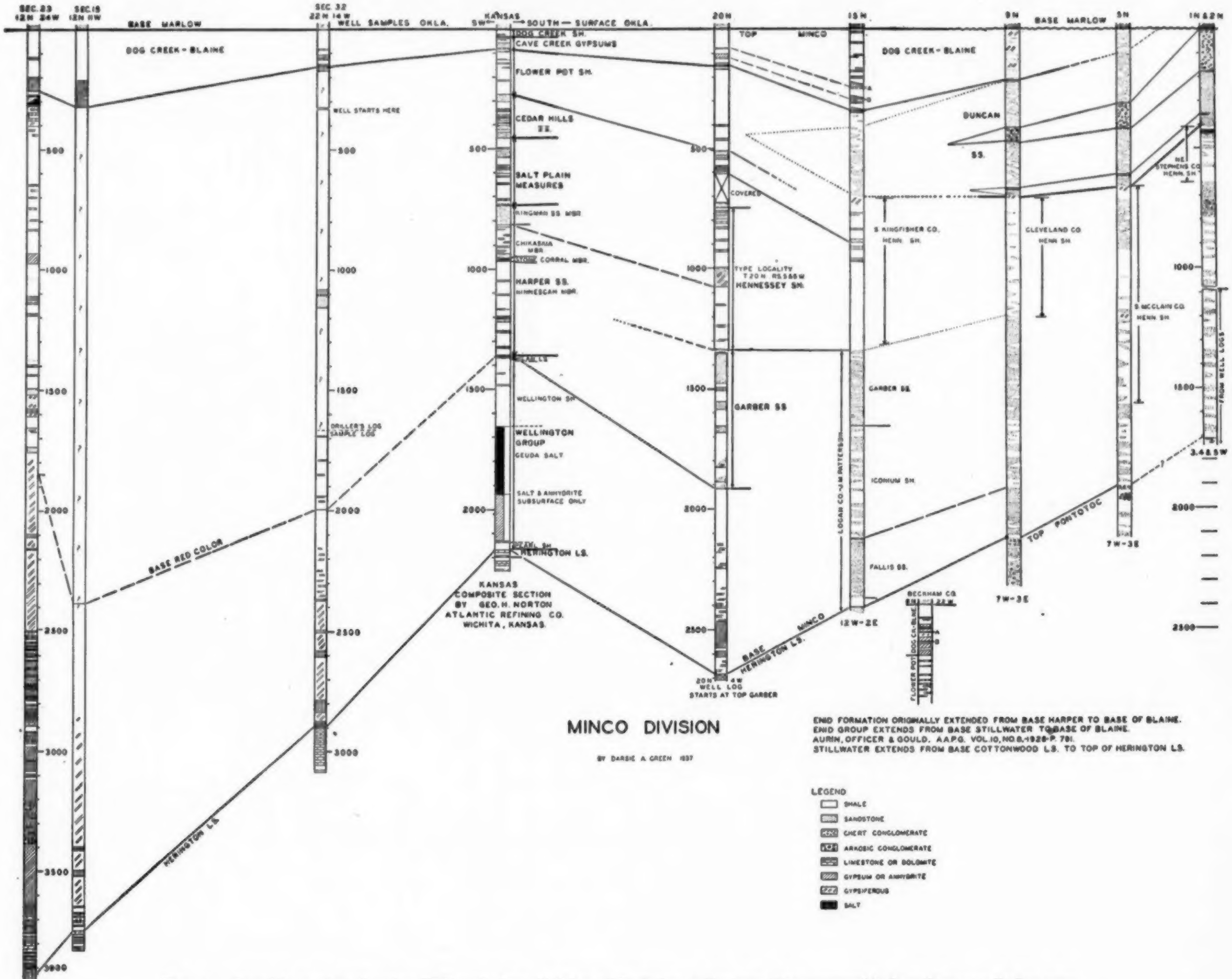


FIG. 2.—Graphic section showing "Minco" time division of Permian sediments. For geographic locations, see Index map.

In a general way Figure 2 shows the gradations which occur within the Minco. The composite Kansas section, contributed by George H. Norton, has been used as a key position in assembling these sections. On the right, five surface sections show the gradations southward to the vicinity of the Arbuckle Mountains. On the left, three sample well logs in western Oklahoma show the change in sedimentary facies in the deeper part of the Anadarko basin.

Attention is directed to the variable thickness of this division, 1,700 feet at the west end of the Arbuckle Mountains and 3,900 feet in the Anadarko basin. This may be attributed to contemporaneous uplifts in the mountains and downwarpings in the basin. Attention is also directed to the different stratigraphic positions of the prominent sandstone masses which occur in different areas. Many difficulties have been encountered when attempts have been made to divide the sections found in the various localities into units that would fit a standard set of formations described at some far distant type locality. The section, T. 20 N., shows the type section for the Hennessey shale and approximately the type section for the Garber sandstone. The sections on the south show some of the published correlations regarding these formations and indicate that the names should have been applied as descriptive terms indicating certain types of materials, rather than as formation names. Many correlations have been presented to show exact correlations between various sandstones of the Kansas section and the Duncan of the southern area.

The Marlow overlap which has previously been described is here shown in a little more detailed manner than in the writer's former paper. This unconformity cuts lowest into the Minco sediments over the pre-Marlow anticlines in southeastern Grady County and northeastern Stephens County. Farther west, where the upper Duncan grades to shale and the Blaine beds reoccur, the unconformity at the base of the Marlow could hardly be missed even though the relief of the unconformity is never so great.

The gradations of sediments show that the clastic materials of Minco age came in from various directions. The Garber delta came into the central area from the east in early Minco time. At a later time the sandstones in the Kansas section came in probably from the north or northwest. They finger out southward in west-central Oklahoma. The Garber sandstones wedge out on the north, west, and south. In the subsurface of the north Texas Panhandle another thick sandstone section occurs in the upper part of the Minco which probably had a western source. Around the west end of the Arbuckle Mountains another great delta came in bringing sediments from the

FIG. 2.—Graphic section showing "Minco" time division of Permian sediments. For geographic locations, see Index map.

exposed Pennsylvanian in the highly folded Ardmore basin. This delta may well be named the Tussy delta, the name being from the small village located in northwestern Carter County. During early Minco time the Tussy delta spread sediments northward and northeastward, causing tongues from this delta to interfinger with the southward tongues from the Garber delta in McClain County. It also spread sediments westward to the Wichita Mountains where they overlap on the Arbuckle limestone. Pebbles of Arbuckle limestone are common in these sandstones near the Wichita Mountains, but a careful search has not revealed any arkosic materials. On account of the present relative positions of the Arbuckle limestone and the igneous rocks in these mountains, this absence of arkose offers a problem concerning their relative positions during early Minco time.

At the west end of the Arbuckles, arkosic materials record uplifts in these mountains during early and middle Minco time. Following these uplifts there was a short time of quiescence during which the Hennessey type shale was deposited. This was followed by a period of uplifts along the main shore line south of the Arbuckles which resulted in the deposition of the sandstones in the Duncan wedge and the still higher sandstones which contaminated the Dog Creek-Blaine section. These highest sandstones were the last Tussy delta deposits. The arkosic materials which occur in the middle part of the Duncan wedge record another uplift in the west end of the Arbuckle Mountains. The sections show, too, that during middle Duncan time Tussy delta deposits had their maximum northward limits. East-west sections show that it was also the middle Duncan that extended farthest west.

When the Dog Creek-Blaine and Flower-pot shale are traced toward the Tussy delta from either the north or the west, the lower part of the section is the first to lose its identity. The Medicine Lodge gypsum, which is the basal bed in the Dog Creek-Blaine formation, loses its identity near El Reno, in Canadian County. Tracing this gypsum bed from the west, it is lost a few miles southeast of Sentinel, in southwestern Washita County. The higher dolomite beds "A" and "B," which are at the base of the Lovedale and Shimer gypsum beds, respectively, according to Evans'[10] classification, extend much farther toward the delta. The "A" bed has been traced to the south part of Canadian County from the north, and from the west it has been traced into the west edge of Caddo County, where it is lost by gradation in Sec. 28, T. 7 N., R. 13 W., a few miles southeast of the town

[10] Noel Evans, "Stratigraphy of Permian Beds of Northwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 4 (April, 1931), p. 413.

of Carnegie. These conditions indicate that the Tussy delta was receding in late Minco time.

Attention is called to the section on Figure 2 which shows the upper Minco beds in Beckham County, where the Dog Creek-Blaine formation contains more gypsum than at any other locality examined along the outcrops in Oklahoma or Kansas. The 200 feet of typical Flower-pot shale in this section contains many thin beds of gypsum. This westward increase in gypsum suggests that the thicker "Blaine" sections in Texas may include both younger and older beds than those commonly known as "Blaine" in Oklahoma.

South of the town of Carter, in Beckham County, the "A" dolomite was described as the Mangum dolomite by Suffel.[11] The "A" dolomite is the bed in which the pelecypods are common; however, these fossils do ocçur in the "B" dolomite in some localities. The best locality for the study of these fossils is southeastern Blaine County and northwestern Canadian County.

Near the close of Minco time there was regional warping and some local folding, followed by peneplanation. A condition of general quiescence prevailed at the close of Minco time.

UPPER RED-BEDS DIVISION

This division starts at the base of the Marlow formation and extends upward to the Tertiary overlap above the Elk City sandstone. As indicated in Figure 3 this includes the Whitehorse group and the Quartermaster, which is also considered a group.

In a general way the base of this division agrees with Roth's base of the "Custer"; however, there are too many discrepancies in his present descriptions to permit the acceptance of the term "Custer" in Oklahoma. In Kansas and northwestern Oklahoma the base of Roth's "Custer" is at the base of the Marlow. In Grady County his contact is at the base of the Verden channel sandstone, which is approximately 75 feet above the base of the Marlow. In Roth's recent paper,[12] no correction was made concerning the Grady County contact, but (in his Figure 13) he has shown a photograph of "Fossil sand dunes in basal Custer, SW. cor. of Sec. 19, T. 7 N., R. 13 W., Oklahoma." Evidently the wrong location has been given for this picture since any exposures at this location are definitely below the Dog Creek-Blaine. In this recent publication Roth has described

[11] G. G. Suffel, "Dolomites of Western Oklahoma," *Oklahoma Geol. Survey Bull. 49* (January, 1930), pp. 58–62.

[12] Robert Roth, "Custer Formation of Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 4 (April, 1937).

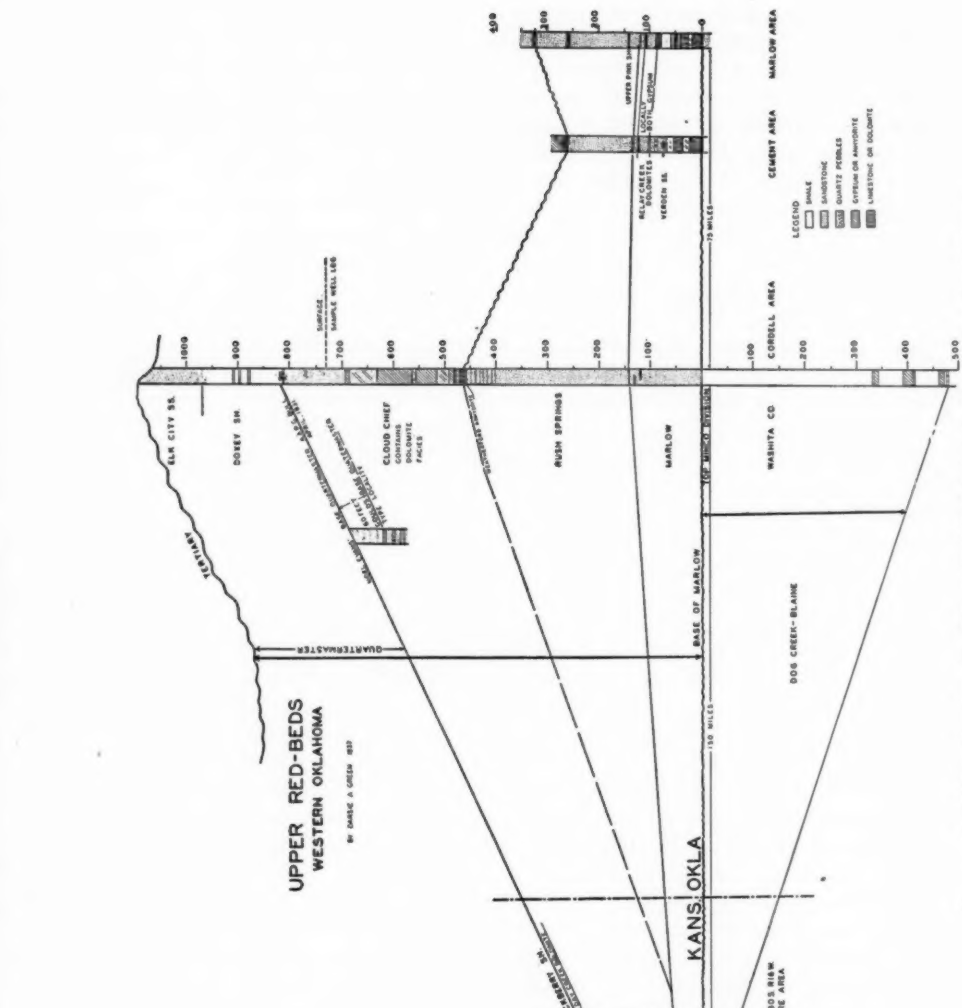


FIG. 3.—Graphic section showing "Upper Red-Beds" time division of Permian sediments. For geographic locations, see Index map.

many features which indicate that the base of his "Custer" in Texas is the same as the base of the Marlow in Oklahoma and Kansas. Conglomerate pebbles similar to those described at the base of the "Custer" in Fisher, Nolan, and Coke counties are common in the base of the Marlow in Oklahoma. The unconformable contacts are in perfect agreement in the two areas. From this it appears that the base of the Marlow formation is the most continuous time line in the Permian basins.

At the southeast end of the Anadarko basin the most abrupt sedimentary and environment change is shown where stratified gypsiferous shales and gypsiferous silty sandstones of the Marlow rest unconformably on the deltaic Duncan sandstones. Northward and westward the Marlow loses its gypsiferous facies and, except for the dolomites in its upper part, it occurs as a solid sandstone body.

In Kansas and northwestern Oklahoma the base of the Marlow is the base of Gould's Whitehorse.[13] The sandstone described as the Whitehorse in the Cement area by Reeves[14] is now known as the Rush Springs member of the Whitehorse group and is above the Marlow formation as shown by Sawyer.[15] The writer makes one minor change in the exact location of the upper Marlow contact and raises it about 10 feet above the upper Relay Creek dolomite, where there is a change from Marlow stratification to the poorly stratified Rush Springs. It is along this line that the minor local unconformities have been observed.

The Rush Springs sandstone has a highly variable thickness due both to original deposition and to pre-Cloud Chief erosion. In Kansas the Rush Springs is thought to be absent due to non-deposition. In Washita and Custer counties the Rush Springs is more than 300 feet thick. At Cement the upper part has been removed by erosion and the Cloud Chief gypsum now rests only 130 feet above the base of the Rush Springs.

In the former paper the writer concluded that the Cloud Chief should be grouped with the Quartermaster, since the dolomite facies of the Cloud Chief in the Weatherford area had been described as Quartermaster by Evans.[16] In a more recent paper by Evans[17] the

[13] C. N. Gould, "Geology and Water Resources of Oklahoma," *U. S. Geol. Survey Water-Supply and Irrigation Paper 148* (1905).

[14] Frank Reeves, "Geology of the Cement Oil Field, Caddo County, Oklahoma," *U. S. Geol. Survey Bull. 726-B* (1921).

[15] Roger Sawyer, "Areal Geology of a Part of Southwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8 (1924), pp. 312-21.

[16] Noel Evans, "Stratigraphy of Weatherford Area, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 7 (July, 1928), p. 705.

[17] Noel Evans, "Stratigraphy of Permian Beds of Northwestern Oklahoma," *ibid.*, Vol. 15, No. 4 (April, 1931), p. 431.

base of the Quartermaster was established at the base of the Hackberry shale in Kansas. This is the base of the Doxey shale in western Oklahoma. In this latter publication Evans makes no mention of Quartermaster dolomites and states that at no place in the northwestern area is there any evidence of any unconformity at the base of or within the Quartermaster. The writer agrees with Evans concerning the above conditions and will add that in the area south of the Canadian River there is no unconformity at the base of the Doxey shale in the areas examined. In Washita County the contact between the Doxey shale and the Cloud Chief is clearly one of gradation.

This clarification makes it necessary to abandon considering the Cloud Chief dolomite facies of the Weatherford area as Quartermaster. The Cloud Chief is now classified as the upper member of the Whitehorse group, which is in agreement with the last classification by Evans. The Doxey shale and the Elk City sandstone are considered formations which are included in the Quartermaster group.

The Day Creek dolomite of northwestern Oklahoma and southwestern Kansas was first described by Cragin.[18] Attempts to find this dolomite in central-western Oklahoma led to many mistakes in classification which have now been recognized and corrected. The last paper by Evans, in which he has shown that the Day Creek dolomite is above rather than below the Cloud Chief, is an outstanding contribution. Evans has traced the Day Creek over the Cloud Chief into northern Dewey County, where the Day Creek is lost by gradation. The writer believes he has identified the Day Creek dolomite horizon south of the Canadian River a few miles northwest of the town of Leedy, which is the type locality for Gould's Quartermaster formation. At this point the Day Creek is a short distance above the highest beds Gould included in his Cloud Chief (Fig. 3).

Evans has described the Day Creek dolomite as

> a hard, light gray limestone or dolomitic limestone, 2 feet in thickness. . . The Day Creek commonly contains aggregates of smoky or reddish chert.

He has included in his Day Creek another thin calcitic or dolomitic bed, 3 feet above the main bed.

Evans' classification shows the Whitehorse to extend upward to the base of the Day Creek and the Quartermaster to extend downward to the top of the Day Creek; thus the Day Creek is a thin formation not included in either the Whitehorse group or the Quartermaster group. In areas where the Day Creek dolomite can not be

[18] F. W. Cragin, "Permian System in Kansas," *Colorado College Studies*, Vol. 6 (1896).

recognized it seems advisable to consider it absent from the section.

The change from gypsum to dolomite within the Cloud Chief formation is not peculiar to this formation. Many field geologists are familiar with the manner in which the Weatherford anhydrite occurs as dolomite, gypsum, or anhydrite. The change from dolomite to gypsum in the horizon of the Relay Creek dolomites in the upper part of the Marlow formation is common knowledge. This same change has been observed in beds in the Dog Creek-Blaine formation. The alterations in the Cloud Chief are a bit more difficult to explain than in the other formations and offer a problem for more intensive study. It has occurred to the writer that ascending water may have been responsible for much of the alteration. Observations of the buttes in northern Caddo County show that not only has the capping Cloud Chief material been altered to calcareous material, but the upper 50–75 feet of the Rush Springs sandstone has also been calcified and hardened. The hardened cone-shaped hills which are common in the Cloud Chief formation over eastern Custer and Washita counties strongly suggest local hardening and alteration due to some type of springs.

A most peculiar feature of the Cloud Chief is that some areas have great amounts of gypsum while intervening areas contain practically no gypsum. This unequal distribution shows that variable conditions existed in the basin during the deposition of the Cloud Chief formation.

No attempt will be made to correlate the exposures of red sandstone and shale in Cimarron and Texas counties with the section in west-central Oklahoma.

DISCUSSION: QUARTERMASTER UNCONFORMITY OF WEATHERFORD AREA, OKLAHOMA[19]

NOEL EVANS

Almost any discussion of this paper by Mr. Green must of necessity bring out differences in opinions. These differences should not, however, detract from the importance of the paper. He has presented his views, based on a great amount of work over a large area, and he should be complimented on this work.

[19] Manuscript received, July 27, 1937. This was written as a discussion of Mr. Green's paper, "Permian and Pennsylvanian Sediments Exposed in Central and West-Central Oklahoma," as published in the *Bulletin*, Vol. 20, No. 11 (November, 1936), pp. 1454–75. At the conference in Norman, Oklahoma, May 8, 1937, Mr. Green discussed his paper and changed his classification of the Cloud Chief as a part of the Quartermaster and restored it as a part of the Whitehorse. On this point, we are now in agreement. Since his article, as published in the November, 1936, *Bulletin*, classifies the Cloud Chief as a part of the Quartermaster rather than as a part of the Whitehorse, I think the following discussion is in order.

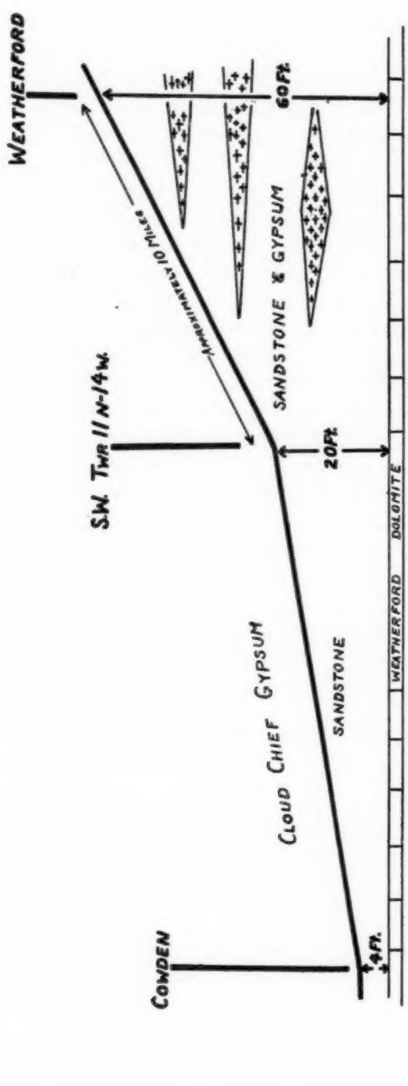


FIG. 4.—Cross section showing relations between Cloud Chief gypsum and Weatherford dolomite.

I am to discuss the Quartermaster unconformity in the Weatherford area and the relationships of the Cloud Chief gypsums. Mr. Green and I are in agreement on part of this, but differ on part of it.

Mr. Green points to an unconformity below the massive Cloud Chief gypsums. He gives the locations of several points where the interval from the Cloud Chief down to the Weatherford dolomite varies. He considers this an indication or proof of an unconformity. I recognize this relationship of the changing interval (Fig. 4), but do not consider it to indicate much of an unconformity, but rather a thickening and thinning of section, which might be called lensing. Forty feet of thinning in 10 miles is not much. There is no conglomerate or particularly irregular contact below the Cloud Chief, but the beds undergo a fairly uniform rate of thinning or thickening. I am willing to concede some kind of a small unconformity here, but can not see it as being of much consequence.

Mr. Green recognizes the great unconformity in the Caddo County Buttes, where an irregular dolomite rests with an irregular contact on varying stratigraphic horizons of the Rush Springs sandstone. Yet he correlates this greater unconformity with the lesser, questionable unconformity at the base of the massive Cloud Chief in the Quartermaster. This, in spite of the great lithologic similarity of the gypsum, sandstone, and shale of the Cloud Chief to these same kinds of rock in the rest of the Whitehorse and their differences in lithology from that of the Quartermaster.

I differ from Mr. Green in this correlation and this classification of the Cloud Chief (Fig. 5). We can approach this question along two lines to determine the age of this major unconformity: (1) what underlies this unconformity? and (2) what overlies this unconformity? In the Caddo County Buttes, we are agreed that varying horizons of the Rush Springs underlie this unconformity and that the contact is irregular. Now, if this unconformity were at the base of the Cloud Chief, there should be some place where the dolomite is just above the unconformity. In most places erosion has removed the overlying beds, but there are a few places where beds do overlie this unconformity dolomite. One such place is in Sec. 5, T. 9 N., R. 13 W., known to many geologists as "Hastings Moore's laboratory." The overlying beds are Doxey (Quartermaster). At another location, near the southeast corner of Sec. 36, T. 11 N., R. 14 W., this basal, commonly conglomeratic, unconformity dolomite, rests on an irregular surface of Rush Springs, though at a higher elevation, about ¾ mile northwest, Doxey beds can be found with no Cloud Chief gypsums intervening. This is in an area where there is no deep-seated slumping to confuse. As the Weatherford dolomite, wherever present in this vicinity, dips regularly, we know that slumping is not present.

All along the contact between the Cloud Chief massive gypsum and the Rush Springs, there is no conglomerate. Yet in the horizon of this dolomite many varying lithologic types are found—dolomite in some localities, purplish platy beds or conglomerate elsewhere, and all rock types may be more or less sandy.

The question most pertinent at this point in this discussion is: does this unconformity dolomite ever rest on anything higher than the base of the Cloud Chief? The answer is yes. About 7 miles west of Weatherford, just south of Highway 66, this conglomeratic dolomite overlies some of the

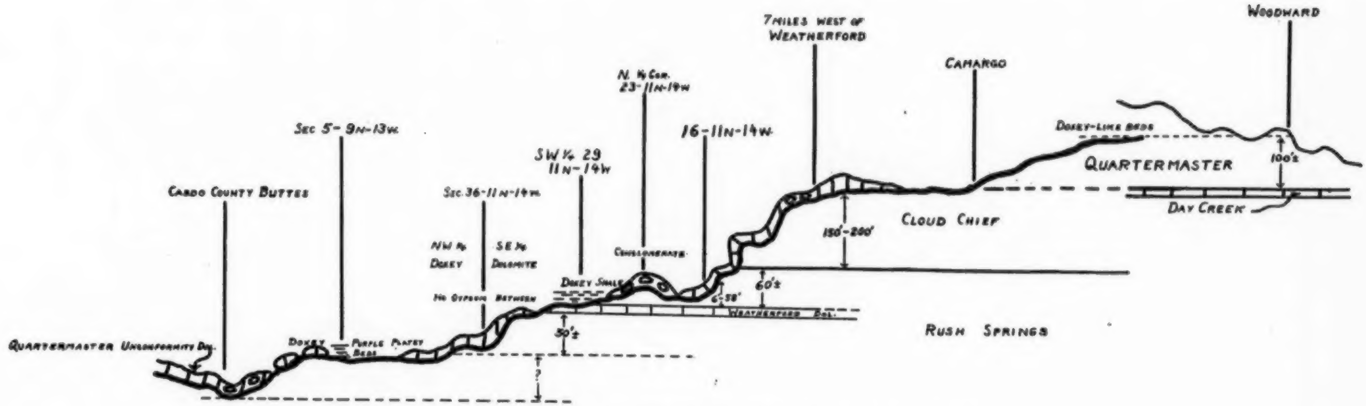


Fig. 5.—Cross section showing relationships of Quartermaster unconformity.

highest of the Cloud Chief gypsums. Another location, mentioned by Mr. Green, is in Sec. 24, T. 12 N., R. 16 W., where he gained the impression that this dolomite was stratigraphically equivalent to the gypsums. I give this a different interpretation. The reason that this dolomite is in juxtaposition with the gypsum is the unconformity below it. There is slumping in this area too. This dolomite is conglomeratic in some places, in others it seems to be a good dolomite without much evidence of conglomerate. In some places veins of dolomitic material fill cracks or joints in the rocks that run in angles up to the vertical. I have seen a few such veins 3 or 4 inches wide. In this same general area, I have seen this unconformity dolomite overlying a massive sandstone bed, which is 30 feet or more above the highest of the massive gypsum beds. I do not think that any of these dolomites could possibly be the equivalent of the Day Creek.

Mr. Green is not alone in suggesting that the dolomites might be chemical alterations of the gypsum, thus correlating them as being stratigraphically the same. While it is easy chemically to change a calcium carbonate to calcium sulphate, this is a difficult chemical reaction to reverse. In a laboratory, with controlled conditions and catalyzing agents, this could be done; but does nature have these controlled conditions and ready catalyzers? What about the magnesium so necessary for the chemical make-up of the dolomite? Gypsum is not a magnesium compound. Would this chemical alteration, even if possible to accomplish, account for the conglomerate that occurs in many places overlying the gypsums and seemingly in juxtaposition with other gypsums? I can not believe it at all likely that any of these dolomites could be chemical alterations of what once were gypsums.

In the general area of Woodward, the lower Quartermaster rests on the Day Creek with no unconformity. However, the lower beds of the Quartermaster are more massive or thicker than those ordinarily in the Doxey. About 100 feet above the Day Creek occur thin-bedded sandstones and shales very similar to the Doxey. It is my opinion that the unconformity we have been discussing not only occurs above the Cloud Chief but really goes still higher and cuts out approximately 100 feet of lowermost Quartermaster.

Summing it all up, I think that this unconformity of Quartermaster age cuts out 100 feet of Quartermaster, 150–200 feet of Cloud Chief, 50–60 feet of Rush Springs above the Weatherford dolomite, and an undetermined thickness, possibly as much as 100 feet of Rush Springs below the Weatherford. These facts combined would account for about 400 feet of section now missing in some places.

Not only because this unconformity is post-Cloud Chief in age, but also because of the very close lithologic resemblance with the rest of the Whitehorse, I still think that the Cloud Chief must be retained as a part of the Whitehorse and not made a part of the Quartermaster.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 12 (DECEMBER, 1937), PP. 1534-1556, 9 FIGS.

UNCONFORMITY AT BASE OF WHITEHORSE FORMATION, OKLAHOMA[1]

OTTO E. BROWN[2]
Holdenville, Oklahoma

ABSTRACT

This paper is intended to present proof that the inability to recognize Dog Creek-Blaine formations in southern Grady, northern Stephens, and Comanche counties, Oklahoma, is not wholly due to the generally accepted idea of lateral gradation, but to an overlapping unconformity at the base of the Marlow member of the Whitehorse formation. Also to show that the State geologic map of Oklahoma is in error in part of this same area.

INTRODUCTION

Some of the most complicated surface geology of Oklahoma is found in the vicinity of the Anadarko basin in Canadian, Caddo, McClain, Grady, Comanche, and Stephens counties. This area was subjected to almost every conceivable type of deposition. Several writers have discussed, in detail, the many phases relative to materials, source, existing conditions, *et cetera*, both from field and laboratory study, until little is left to be said about these subjects. During plane table detail work in all Grady County and parts of the other counties mentioned, several problems developed which have led to the conclusions here stated.

The writer has freely used the many articles and papers published on the structure and stratigraphy relating to the Anadarko basin. He is indebted to O. E. Burst and W. R. Meeks for their assistance in mapping this area. The problems pertaining to this locality have been discussed with Roger W. Sawyer, Nelson B. Potter, Clyde M. Becker, and other geologists familiar with this region.

STRATIGRAPHY

DUNCAN SANDSTONE

The Duncan sandstone is the lowest formation discussed in this paper. The thickness of the Duncan sandstone was originally given by Sawyer[3] as 400 feet. This formation has since been subdivided

[1] Given in part before the annual meeting of the Sigma Gamma Epsilon Fraternity at Norman, Oklahoma, May 8, 1937. Manuscript received, May 12, 1937. Published by permission of the Gulf Oil Corporation.

[2] Geologist, Gulf Oil Corporation (Gypsy Division). Present address, 213 North First Street, Boonville, Indiana.

[3] Roger W. Sawyer, "Areal Geology of a Part of Southwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 3 (May-June, 1924), pp. 312-21.

into two, an upper Chickasha and a lower Duncan sandstone formation.[4]

The best exposures of the contact between the Duncan sandstone and the overlying Chickasha formation in the area under discussion, are in Garvin, Grady, and McClain counties. In a part of Grady and Canadian counties, the Chickasha-Duncan contact is very obscure. It is believed that this is the principal reason such varying thicknesses have been reported for the Duncan sandstone.

The estimated thickness of the Duncan sandstone (restricted) in T. 6 N., R. 4 W., is 130 feet, and near the South Canadian River in T. 10 N., R. 5 W., is 100 feet. Dott[5] gives the thickness as at least 100 feet in western Garvin County. Sawyer[6] measured about 40 feet in Kiowa County. Becker[7] reported 150 feet in Grady County. Anderson[8] said it is 150 feet in western McClain County, and Freie[9] found 180 feet in Stephens, Garvin, and Grady counties.

The Duncan sandstone consists of shales, sandstones, intraformational conglomerates, and a few gypsiferous white sandstone beds, the last ranging from 1 to 2 feet thick. A very good section of the whole formation can be found in T. 3 N., R. 3 W., where the Duncan sandstone is hard, reddish, conglomeratic sandstone, making a prominent escarpment. In T. 6 N., R. 4 W., south of Criner along the east line of Section 25, is a good exposure of the basal bed of the Duncan sandstone in contact with Hennessey shale, of which the upper 25 feet is exposed. This basal Duncan bed is 25 feet or more thick, highly cross-bedded and conglomeratic, being an intraformational conglomerate. It thins northward until in T. 10 N., R. 5 W., it is only 2 feet thick. A shale interval above thickens northward and shows an interbedding of Duncan-type sandstones, with Hennessey-type shales.

The color of the Duncan sandstone varies from buff to light red. The bed described in this paper as the top of the Duncan sandstone

[4] Charles N. Gould, "A New Classification of the Permian Redbeds of Southwestern Oklahoma," *ibid.*, pp. 325-41.

[5] Robert H. Dott, "Geology of Garvin County," *Oklahoma Geol. Survey Bull. 40 K* (May, 1927).

[6] Roger W. Sawyer, "Kiowa and Washita Counties, Oklahoma," *ibid. Bull. 40 HH* (December, 1929).

[7] Clyde M. Becker, "Geology of Caddo and Grady Counties," *ibid. Bull. 40 I* (March, 1927).

[8] G. E. Anderson, "Geology of Cleveland and McClain Counties," *ibid. Bull. 40 N* (July, 1927).

[9] A. J. Freie, "Sedimentation in the Anadarko Basin," *ibid. Bull. 48* (January, 1930).

is recognized by its buff color, and the overlying Chickasha formation is deep red to purple. Chert conglomerate with some arkosic material was found near the top of the Duncan sandstone in the SW. ¼ of T. 4 N., R. 4 W., and a salt bed was found in the upper part of the Duncan sandstone in the central part of T. 6 N., R. 4 W., where cattle have developed "salt licks." The top part of the Duncan sandstone ordinarily forms very good outcrops; the overlying Chickasha formation is more highly cross-bedded and consists chiefly of conglomerates. Few, if any, jack-oaks grow below the top of the Duncan sandstone.

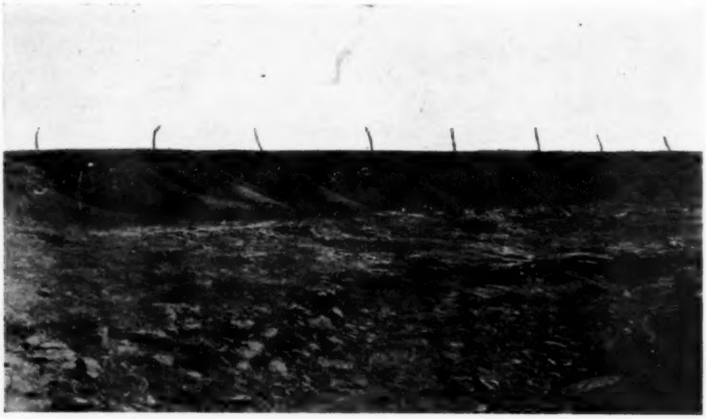


FIG. 1.—Chickasha-Blaine contact, NW.¼, Sec. 29, T. 8 N., R. 7 W., Grady County. Sandstone in foreground, highly cross-bedded, light red in color, represents top of Chickasha formation. Shale above, maroon to deep red, is Blaine formation.

Due to these differences, one is able to locate the top of the formation within 10 or 15 feet as far north as the South Canadian River.

CHICKASHA FORMATION

The type locality of the Chickasha formation is in T. 4 and 5 N., R. 6 W.,[10] and its thickness has been measured at several places. The writer estimates the thickness at 260 feet in T. 4 N., R. 5 W., but because the dip increases toward the Carter-Knox anticline in T. 3 N., R. 5 W., this estimate is only approximate. Gouin[11] measured 200

[10] Clyde M. Becker, "Grady County," *Oklahoma Geol. Survey Bull. 40*, Vol. 2 (July, 1930), p. 112.

[11] Frank Gouin, "The Geology of the Oil and Gas Fields of Stephens County, Oklahoma," *Oklahoma Geol. Survey Bull. 40 E* (October, 1926).

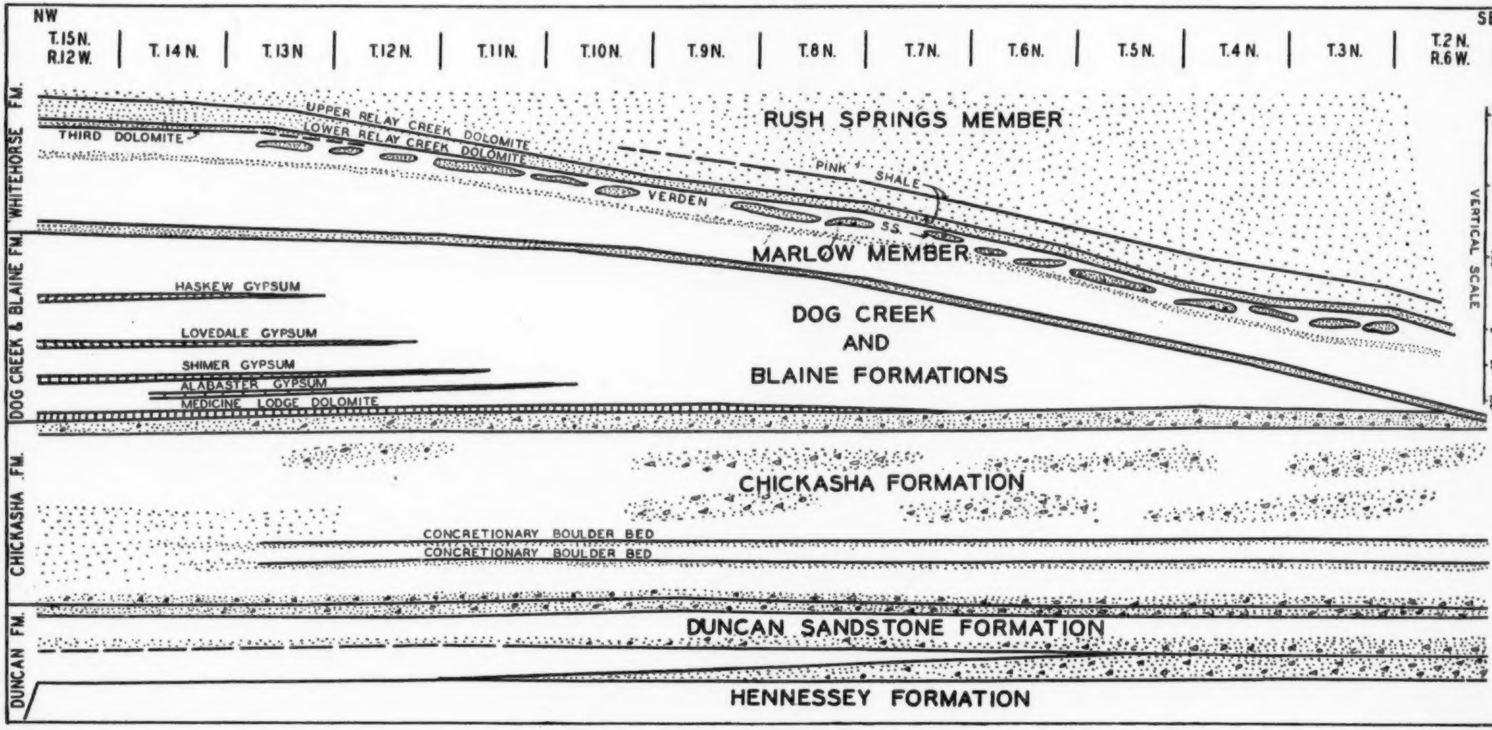


FIG. 2.—Generalized cross section, showing Marlow overlap.

feet in Stephens County, Becker[12] reported a thickness of 145–230 feet in Grady County, Sawyer[13] measured 150 feet in Kiowa County, and Freie[14] measured 160 feet south of Rush Springs. No reliable estimate can be given for Canadian County. There has been much speculation as to how much of it grades laterally into beds of the Dog Creek-Blaine formations farther north.

The basal part of the Chickasha formation is conglomeratic and highly cross-bedded and is deep red to purple. The lower 60 feet are occupied by uncemented sandstone. Concretionary boulders with diameters of 1–2 feet occur in the top of this sandstone. Some good exposures of this bed are in Sec. 16, 27, 29, T. 7 N., R. 4 W. The bed extends from T. 4 N., R. 5 W., to T. 10 N., R. 5 W. The concretions are gypsiferous and probably were formed by water percolating through the overlying shale.

Thirty feet higher in the section is a similar bed at the base of a shale. Highly cross-bedded sandstones and conglomerates with thin intervals of red shales extend from this bed to the top of the Chickasha. The approximate thickness of this sandstone-conglomeratic member is 160 feet. It is best developed along the highway between Chickasha and Alex in T. 5 and 6 N., R. 6 W. Its outcrop is characterized by rounded hills, which are devoid of timber, with the exception of T. 3 and 4 N., R. 5 W., where the formation becomes more sandy and sustains a good growth of jack-oaks. The outcrop continues barren of timber across Grady and Canadian counties. The top bed of the Chickasha is cross-bedded sandstone, 25 or more feet thick, which is discussed more fully in connection with the overlying Blaine formation.

BLAINE-DOG CREEK FORMATIONS

Various thicknesses have been reported for the Blaine and Dog Creek formations near El Reno. Six[15] measured a combined thickness of 475 feet in Blaine County. Evans[16] estimated the Blaine formation at 90 feet, and Becker[17] reported a combined thickness of the Blaine-Dog Creek formations of 120–130 feet.

[12] Clyde M. Becker, *op. cit.*, p. 112.

[13] Roger W. Sawyer, *op. cit.*

[14] A. J. Freie, *op. cit.*

[15] Ray L. Six, "Blaine County," *Oklahoma Geol. Survey Bull. 40*, Vol. 2 (July, 1930), p. 386.

[16] Noel Evans, "Stratigraphy of Permian Beds of Northwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 4 (April, 1931), pp. 405–39.

[17] Clyde M. Becker, *op. cit.*

The combined thickness of the Blaine-Dog Creek formations near El Reno is estimated at 260 feet. In T. 9 N., R. 7 W., where the top of the Dog Creek formation, as exposed, and the base of the Blaine formation come nearest together ($1\frac{1}{2}$ miles) the interval measured is 230 feet, which is considered fairly accurate. In the south part of T. 6 N., R. 7 W., and the north part of T. 5 N., R. 7 W., the contacts are within a mile of each other and the interval measured is approximately 130 feet. From the south line of T. 6 N., R. 7 W., southward, the Blaine-Chickasha contact becomes less distinct and in T. 3 N.,

FIG. 3.—Chickasha-Blaine contact, NE. $\frac{1}{4}$, NE. $\frac{1}{4}$, Sec. 21, T. 8 N., R. 7 W., Grady County. Farthest south point at which basal Blaine dolomite was recognized north of Anadarko basin.

R. 5 and 6 W., it is doubtful whether any of the Blaine formation exists. The writer is of the opinion that all of the Dog Creek formation is gone.

The basal bed of the Blaine formation as defined in this paper is the fossiliferous dolomite bed, which crosses the east line of Sec. 29, T. 12 N., R. 7 W. The dolomite overlies the cross-bedded sandstones of the Chickasha formation, which crop out in Sec. 21, T. 7 N., R. 6 W. No fossils were found in this lower dolomite bed between T. 12 N., R. 7 W., and T. 7 N., R. 14 W., on the south side of the Anadarko basin. The basis for the correlation of the dolomite bed found in T. 7, 8, 9 N., R. 6, 7, W., with the dolomite bed near El Reno, is the massive cross-bedded sandstone directly below, which is mapped as the top of the Chickasha formation.

One of the best exposures of the Blaine-Chickasha contact is in the SE. ¼ of Sec. 16, T. 9 N., R. 6 W., where a section of 50 feet or more is exposed. The dolomite bed is somewhat sandy at this place, but the massive, cross-bedded, light-colored sandstone representing the top of the Chickasha formation differs so completely from the maroon to deep red color of the Blaine formation, that the two formations can readily be separated. The Blaine, at this place, consists of shales and gypsiferous sandstone streaks ranging from a few inches to a foot in thickness, some of which turn to a pure crystalline gypsum in a very short distance.

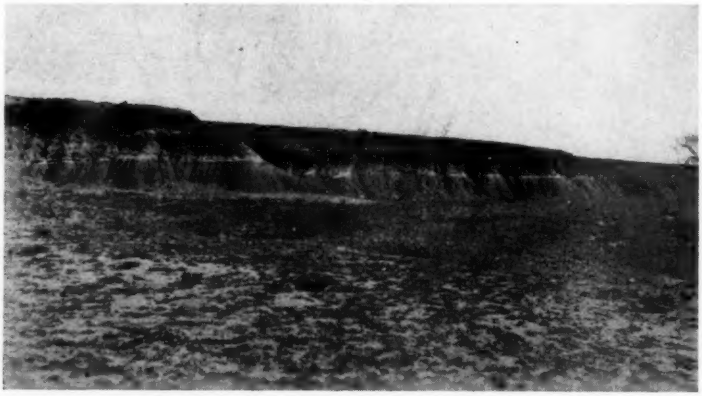


FIG. 4.—Blaine formation, SE. ¼, SW. ¼, Sec. 15, T. 6 N., R. 7 W., Grady County. Notice evenly bedded white streaks characteristic of basal Blaine. Floor is Chickasha.

At the following locations are some of the best exposures of this contact: Sec. 29, T. 12 N., R. 7 W.; Sec. 21, T. 11 N., R. 6 W.; SE. ¼, Sec. 16, T. 9 N., R. 6 W.; NE. ¼, Sec. 28, T. 9 N., R. 7 W.; SE. ¼, Sec. 29, T. 9 N., R. 7 W.; center, SW. ¼, Sec. 17, T. 8 N., R. 7 W.; 1,000 feet west of the Washita River bridge in the NE. ¼, Sec. 18, T. 7 N., R. 7 W.; NE. corner, Sec. 5, T. 7 N., R. 7 W.; along the old highway through the center of Sec. 23, T. 7 N., R. 7 W.; east of the Chickasha airport, near the center of Sec. 10, T. 6 N., R. 7 W.; along the east line of Sec. 15, T. 6 N, R. 7 W.; 100 yards north of the Ninnekah Cemetery in Sec. 34, T. 6 N., R. 7 W., and along the south line of Sec. 36, T. 4 N., R. 6 W.

No division of the Blaine-Dog Creek formations is given in this paper as the two formations are nearly identical in lithologic char-

acter and color. Six[18] believes that an unconformity exists at the base of the Blaine formation in Blaine County. No evidence of this unconformity was found in the area under discussion.

In the SE. ¼, SW. ¼, Sec. 15, T. 6 N., R. 7 W., and in Sec. 12, T. 5 N., R. 7 W., are several thin white, evenly bedded gypsiferous sandstone beds. These exposures are typical of the basal beds of the Blaine formation. Southward from these locations beds resembling Chickasha-type sediments appear and continue to the axis of the Anadarko basin. The thin, white, evenly bedded sandstone beds directly above the purple bed representing the top of the Chickasha

FIG. 5.—Marlow-Dog Creek contact, SW. ¼, NW. ¼, Sec. 9, T. 9 N., R. 7 W., Grady County. Figure in background stands on contact. Notice weathered-out crystals of gypsum (Dog Creek) in lower part of picture.

formation are present when not cut out by overlap. To say there was no lateral gradation would be erroneous, yet the writer believes that the top of the Chickasha formation in this area can be recognized. The dark red to maroon color continues as far south as these formations were found. The Blaine-Dog Creek formations have the same depositional characteristics as the underlying Chickasha-Duncan formations, being highly cross-bedded in places and grading into coarser materials southward, which is thought to be in the direction whence the materials came. A measurement of the Blaine-Dog Creek formations was taken in Sec. 13, T. 7 N., R. 14 W., and was found to be 50 feet.

[18] Ray L. Six, *op. cit.*

WHITEHORSE FORMATION

MARLOW MEMBER

The Marlow member of the Whitehorse formation has been ably described by Sawyer.[19] He says of this formation:

> Above the Duncan sandstone is the Marlow formation, which consists of brick-red shales and even-bedded brick-red sandstones, with bands of fine white sand and sandy gypsums. The entire formation is gypsiferous, many of the shales containing veins of satin-spar and the sandstones contain more or less gypsum. A thin layer of almost pure gypsum, about 1 foot thick, is found at the top of this formation. The thickness of the Marlow formation is about 120 feet.

The locations of the contact given by Sawyer, between the Marlow formation and underlying beds of the Dog Creek-Blaine formations, were identified.

The Marlow member of the Whitehorse formation ranges in thickness from 175 feet in T. 15 N., R. 12 W., to 105 feet in T. 2 N., R. 6 W. The writer would include the 11 to 28-foot interval between Sawyer's 1-foot gypsum bed and the upper Relay Creek dolomite in the Marlow member.

The sediments at the lowest point of the Anadarko basin are finer, with a greater amount of shale, than those 75 miles farther north, which shows a reverse condition from that which prevailed during Duncan, Chickasha, Blaine, and Dog Creek time. In Sawyer's description of the Marlow member, no recognition was given the two thin dolomite beds found at the top of this division of the Whitehorse formation and no previous maps have shown the areal distribution of these beds (Fig. 8). The 1-foot gypsum bed mentioned by Sawyer has been identified as the lower Relay Creek dolomite.

The Relay Creek dolomites reach their maximum thickness near the town of Greenfield in T. 15 N., R. 12 W., and are more or less continuous through 40 townships, which are included in this report. They were mentioned by Stephenson[20] as limestones and were given the same stratigraphic horizon as the Verden sandstone.

In the vicinity of Greenfield, three separate beds were recognized. The second dolomite bed is 7 feet above the lowest and the third is 28 feet higher. The upper two beds have been found directly above the Verden sandstone. This places Stephenson's Verden sandstone cor-

[19] Roger W. Sawyer, "Areal Geology of a Part of Southwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 3 (May–June, 1924), pp. 312–21.

[20] C. D. Stephenson, "Observations on the Verden Sandstone of Southwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 3 (May–June, 1925), pp. 626–31.

relation as not higher than the lowest bed. The interval between the two upper beds decreases from 28 feet in T. 15 N., R. 12 W., to 11 feet in T. 6 N., R. 8 W., and increases slightly to 14 feet in T. 2 N., R. 6 W. If the Marlow section is Permian, this would be contrary to the rule that all Permian sediments thicken toward the Anadarko basin. These beds change from sandy dolomite to gypsum and back again to dolomites in less than ¼ mile. In Sec. 28, T. 8 N., R. 9 W., both dolomite beds are replaced by gypsum, ½–1 foot thick.

Pink shale, about 3 inches or less thick, 1 foot under the upper Relay Creek dolomite, was first noticed in T. 9 N., R. 10 W., and was found to continue southward in the other part of the area covered by this paper. It has also attained the local name of "Gracemont shale."

In the vicinity of Agawam, in Sec. 30, T. 5 N., R. 7 W., another pink shale occurs. This shale is 25–30 feet above the upper Relay Creek dolomite and is found to be continuous southward around the basin. In the sandstone cliffs in Sec. 28, T. 10 N., R. 10 W., a recognizable band was found approximately 30 feet above the upper Relay Creek dolomite, which the writer has correlated as this shale horizon.

The Verden sandstone has been discussed by several writers. Reeves[21] writes:

> The presence of small marine shells and the apparent up-stream cross-bedding, suggests that a strong tidal current flowed up this stream from the sea.

Sawyer[22] says:

> Detail work shows that the Verden sandstone follows the strike of the rocks closely and would seem to mark an old shore line of a body of water, which existed during a part of the time in which the Marlow formation was deposited.

The geologic map of Oklahoma shows the Verden sandstone outcrops as extending from T. 2 N., R. 6 W., to T. 8 N., R. 9 W., a short distance north of the Washita River. As has been reported by Stephenson, it continues much farther northward. The accompanying map shows the outcrops to be 75 miles in length, and ½ mile wide at the widest place, in Secs. 9 and 10, T. 6 N., R. 8 W. Contrary to Reed and Melan,[23] it does dip. From Sec. 5, T. 12 N., R. 9 W., where the

[21] Frank Reeves, "Geology of the Cement Oil Field, Caddo County, Oklahoma," *U. S. Geol. Survey Bull. 726 B* (1922).

[22] Roger W. Sawyer, *op. cit.*

[23] R. D. Reed and Norman Melan, "The Verden Sandstone," *Jour. Geol.*, Vol. 32, No. 2 (1924), pp. 150–67.

elevation is 1,550 feet, it dips to 1,220 feet in Sec. 4, T. 6 N., R. 8 W., and rises again to 1,290 feet in Sec. 13, T. 2 N., R. 6 W.

The Verden sandstone was not found to be higher than the lower Relay Creek dolomite, or lower than the first gypsiferous sandstone bed approximately 28 feet below the lower Relay Creek dolomite. This shows that if it is a river-channel deposit, it did not cut through the formation in which the stream was flowing, which is considered highly improbable. This gives the Verden sandstone the same stratigraphic horizon as any other bed in the Marlow member. The thickening and thinning of the Verden sandstone is everywhere at the expense of the shale interval in which it is deposited. The Relay Creek dolomites are very unevenly deposited directly above the Verden sandstone, which suggests near-shore deposition in the Marlow sea. The Verden sandstone is believed to be a reef sand or beach barrier.

Little cross-bedding was found in the Marlow, other than that in the Verden sandstone and in another thin bed near the base of the Marlow section. This difference of deposition has been recognized by practically all geologists who have worked in this area. Roth[24] states:

> Associated with the base of the Custer is frequently a very fine conglomerate composed of well-worn small pebbles of chert of various sorts, of which the degree of rounding is quite distinctive. These fine conglomerates are commonly associated with the channel sandstones and may be observed to an advantage in the SW. ¼ of SW. ¼ of SW. ¼, Sec. 18, T. 4 N., R. 6 W., Grady County, Oklahoma.

Roth suggests the name Custer for the beds between the Lower Cretaceous and the top of the Dog Creek formation. The writer is familiar with the location as given by Roth and believes he is describing the Verden sandstone in Sec. 18, rather than the base of the Custer which is 1 mile north of this location and 80 feet lower in the section.

Roth also states (p. 701):

> The writer was unable to find a definite line of contact between these two members of the Whitehorse and field work shows that the lower part of the Whitehorse as described by Sawyer, that is the Marlow member, really belongs with the underlying Dog Creek and Flower-Pot shales.

Sawyer followed the base of this formation and properly included it in the Whitehorse.

Becker[25] has discussed in two different papers an outcrop of the Marlow in the central part of Sec. 4, T. 5 N., R. 7 W.

[24] Robert Roth, "Evidence Indicating the Limits of Triassic in Oklahoma, Kansas, and Texas," *Jour. Geol.* (November–December, 1932), p. 720.

[25] Clyde M. Becker, *op. cit.*, p. 110.

Included in these formations are two sandstone members: the upper 30 to 40 feet below the base of the Whitehorse [Rush Springs member] is 20 to 25 feet thick, brownish red in color and contains considerable gypsum. It is frequently confused with the base of the Whitehorse. This bed is exposed in a long ledge in the hills south of Verden, and extends eastward to a point three miles west of Chickasha. The other sandstone member is approximately 40 feet below the formation just described, and 30 feet above the base of the Blaine formation. It is a dark red coarse-grained somewhat conglomeratic sandstone averaging 10 feet in thickness, and is frequently mistaken for the upper portion of the Chickasha formation. This bed is well exposed in a scarp south of the Little Washita River near the center of Sec. 4, T. 5 N., R. 7 W.

Becker[26] states further:

This shows the relationship of the base of the 600 feet of section below the base of the Whitehorse, or Marlow. The proof of the relationship of the upper part of this section is shown in an exposure in Sec. 4, T. 5 N., R. 7 W., Grady County, south of Little Washita River, where the top of the Chickasha is in contact with the base of the Whitehorse.

The writer is well acquainted with these locations and believes the two sandstones mentioned in the report on Grady County are the same bed. It is not 30 feet above the base of the Blaine, but 130 feet above. The outcrop mentioned in Sec. 4, T. 5 N., R. 7 W., is the base of the Marlow formation. Since this is the only outcrop in that section, the two statements made by Becker appear to conflict.

At the following locations are some of the best exposures of the contact between the Marlow and the underlying Dog Creek-Blaine formations, namely: along the line between Sec. 1, 2, T. 12 N., R. 9 W.; near the SW. corner of Sec. 19, T. 12 N., R. 8 W.; SW. corner of Sec. 36, T. 12 N., R. 9 W.; near the base of an outlier of Verden sandstone, NE. $\frac{1}{4}$, NW. $\frac{1}{4}$, Sec. 4, T. 11 N., R. 9 W.; center of the east line of Sec. 25, T. 11 N., R. 9 W.; east of the main highway between Minco and Pocasset, SW. $\frac{1}{4}$, NW. $\frac{1}{4}$, Sec. 7, T. 9 N., R. 7 W.; NE. corner of Sec. 5, T. 8 N., R. 8 W.; along the west line of Sec. 19, 500 feet south of the quarter corner of T. 9 N., R. 7 W; just below the sandstone ledge on which the Verden water tower rests in Sec. 18, T. 7 N., R. 8 W.; 1,000 feet north of the U. S. G. S. B. M., located 800 feet west of the center of the south line of Sec. 36, T. 7 N., R. 8 W.; NW. $\frac{1}{4}$, Sec. 17, T. 6 N., R. 7 W.; the prominent point, jutting out into the south-central part of Sec. 4, T. 5 N., R. 7 W.; near the NE. corner of Sec. 36, T. 5 N., R. 7 W.; 600 feet south of the quarter corner along the east line of Sec. 35, T. 4 N., R. 6 W.; near the center of the SW. $\frac{1}{4}$, Sec. 18, T. 2 N., R. 5 W.; and 200 feet north of the SW. corner of Sec. 21, T. 2 N., R. 6 W.

[26] Clyde M. Becker, "Structure and Stratigraphy of Southwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 1 (January, 1930), p. 51.

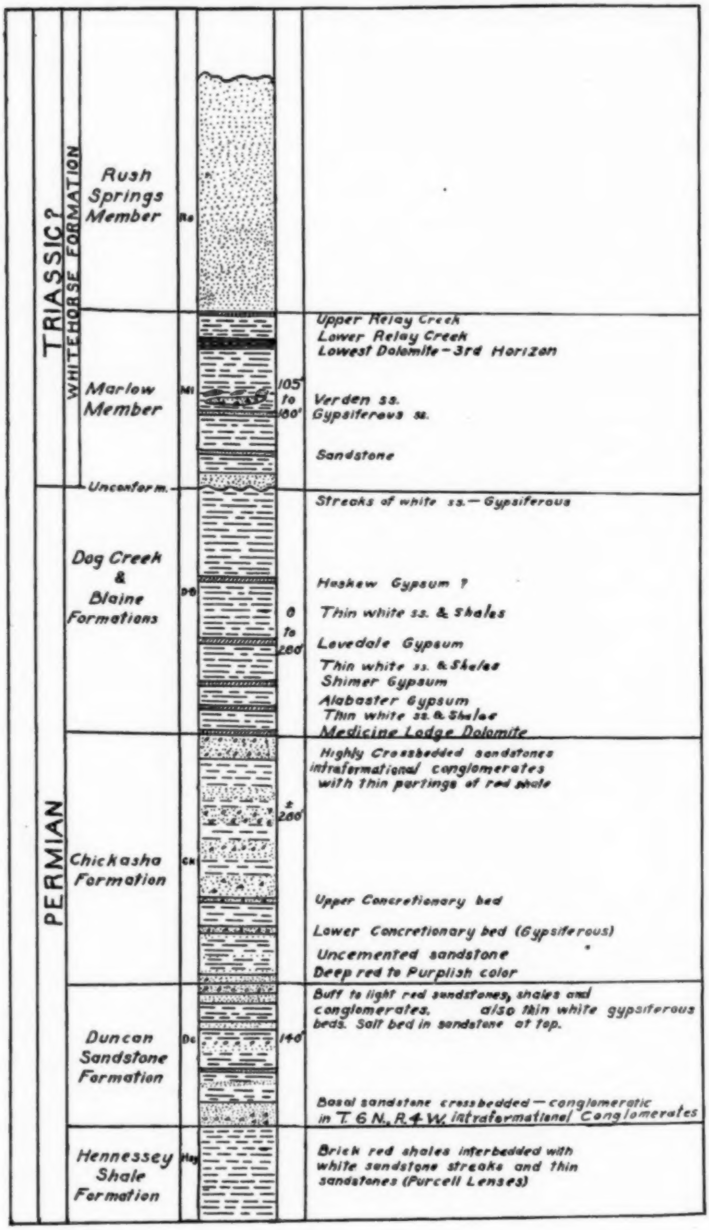


FIG. 6.—Columnar section of formations exposed in Chickasha region, Oklahoma.

RUSH SPRINGS MEMBER

This formation has been well described by Reeves[27] as follows.

Except in the Cement uplift, this rock is a friable, reddish-brown, cross-bedded to regular-bedded sandstone which weathers rapidly, producing a thick soil of sand that is blown about by the wind and in some localities piled up into sand dunes. Streams cut deep gorges in the sandstone, exposing it in the walls of narrow canyons. . . .

The logs of wells in the Cement area indicate that its thickness there is about 250 feet. At the base of the Whitehorse sandstone cliff which forms the river bluffs 1 mile north of the northeast corner of Tonkawa Township [T. 6. N., R., 10 W.] there occurs a 2-foot bed of white gypsum underlain by red gypsiferous shales.

As he has treated this as the base of the Whitehorse sandstone, it is evident that the Marlow member was not included in his description of the Whitehorse sandstone. The writer has found this gypsum bed to be the lower Relay Creek dolomite. It is a gypsum bed in this locality.

MARLOW-DOG CREEK-BLAINE UNCONFORMITY

The accompanying map (Fig. 7) shows structure contours on beds of the Marlow, with the strike west-northwest. This is in contrast to the strike found on the Blaine-Chickasha contact which is north-south, and is considered proof of an unconformity, since these outcrops can be followed. Also, the thinning of the Blaine-Dog Creek interval from approximately 260 feet, at El Reno, T. 12 N., R. 7 and 8 W., to 130 feet near Ninnekah, in the south part of T. 6 N., R. 7 W., suggests an unconformity. The basal Marlow or contact bed is everywhere evenly stratified. This is not true of the horizon on which, in places, it rests, which is cross-bedded with various beds of the Dog Creek-Blaine in contact with the basal Marlow. This is interpreted as meaning that the Marlow has cut across the Dog Creek, with each succeeding exposure dropping lower and lower in the Dog Creek-Blaine section southward. Other writers have noticed evidence of an unconformity at the base of the Whitehorse. Six[28] states:

The Dog Creek is conformable upon the Blaine and is overlain unconformably by the Whitehorse sandstone.

Kite[29] has observed:

The lower Whitehorse sandstone outcrops in about six townships in

[27] Frank Reeves, "Geology of the Cement Oil Field, Caddo County, Oklahoma," *U. S. Geol. Survey Bull. 726 B* (1922), p. 51.

[28] Ray L. Six, "Blaine County," *Oklahoma Geol. Survey Bull. 40*, Vol. 2, p. 391.

[29] W. C. Kite, "Kingfisher and Canadian Counties," *ibid.*, p. 196.

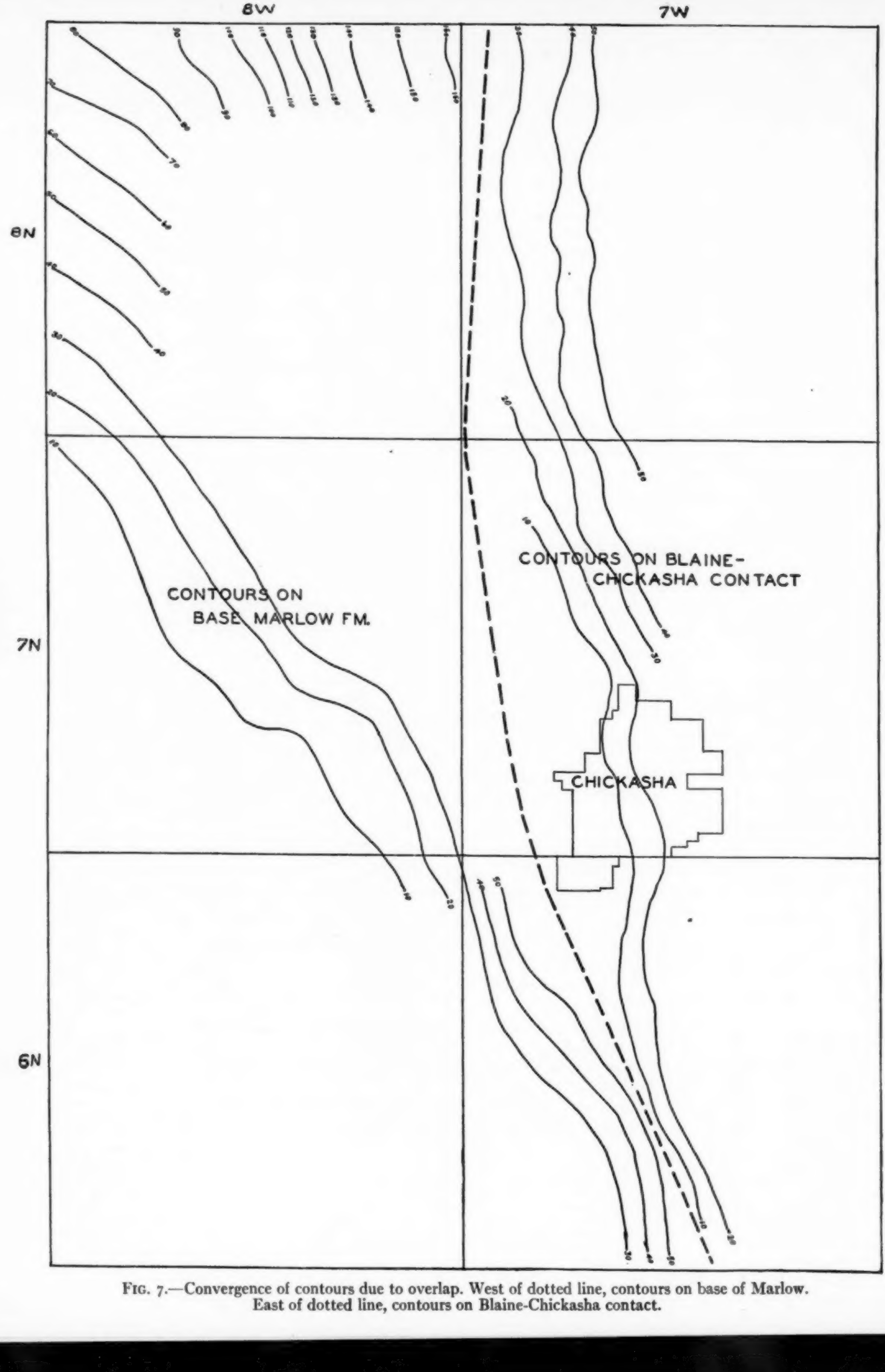


FIG. 7.—Convergence of contours due to overlap. West of dotted line, contours on base of Marlow. East of dotted line, contours on Blaine-Chickasha contact.

southwestern Canadian County. It is just above the Dog Creek shales and apparently lies unconformably on them.

Gouin[30] has written:

From Comanche County to the east end of the Anadarko basin the Dog Creek shale is non-existent, the Whitehorse sandstone resting directly upon the topmost gypsum member of the Blaine.

The writer is in full accord with the statement that the Dog Creek is non-existent, and does not believe that any of the Blaine is present in T. 2 N., R. 5 and 6 W., where the outcrops turn back toward the northwest around the axis of the Anadarko basin.

In a previous report Gouin[31] states:

Above the Chickasha formation in the extreme north-central part of the county, named in order from the oldest to the youngest formations, are the Blaine gypsum, Dog Creek shale and Whitehorse sandstone.

This is taken as a contradictory statement to the previous citation. The maps accompanying the report define the limits of the Marlow, rather than the Dog Creek as shown.

Gould and Lewis[32] have stated:

The senior author is of the opinion that future investigations may show that the Dog Creek shales and Whitehorse sandstone will be found to merge farther west. On the other hand, the junior author believes that the sediments forming the Dog Creek shales came from the southeast and that the formation is separated by a continuous unconformity from the Whitehorse sandstone, which is believed to have come from the northwest, the unconformity dying out to the west with the disappearance of the Dog Creek shales.

The writer agrees with Lewis as regards source of sediments and unconformable relationships.

Freie[33] says:

The Dog Creek lies conformably above the Blaine gypsum ledges in the western part of the Anadarko Basin and is also believed to be conformable with the gypsiferous Blaine shales and siltstones in the eastern area. It is probably unconformable under the Whitehorse sandstone throughout the basin.

Roth[34] states:

[30] Frank Gouin, "Comanche County," *ibid.*, p. 211.

[31] Frank Gouin, "Stephens County," *ibid.*, p. 24.

[32] Charles N. Gould and Frank E. Lewis, "The Permian of Western Oklahoma and the Panhandle of Texas," *Oklahoma Geol. Survey Cir. 13* (December, 1926), p. 21.

[33] A. J. Freie, "Sedimentation in the Anadarko Basin," *Oklahoma Geol. Survey Bull. 48* (January, 1930), p. 55.

[34] Robert Roth, *op. cit.*, pp. 688–89, 713.

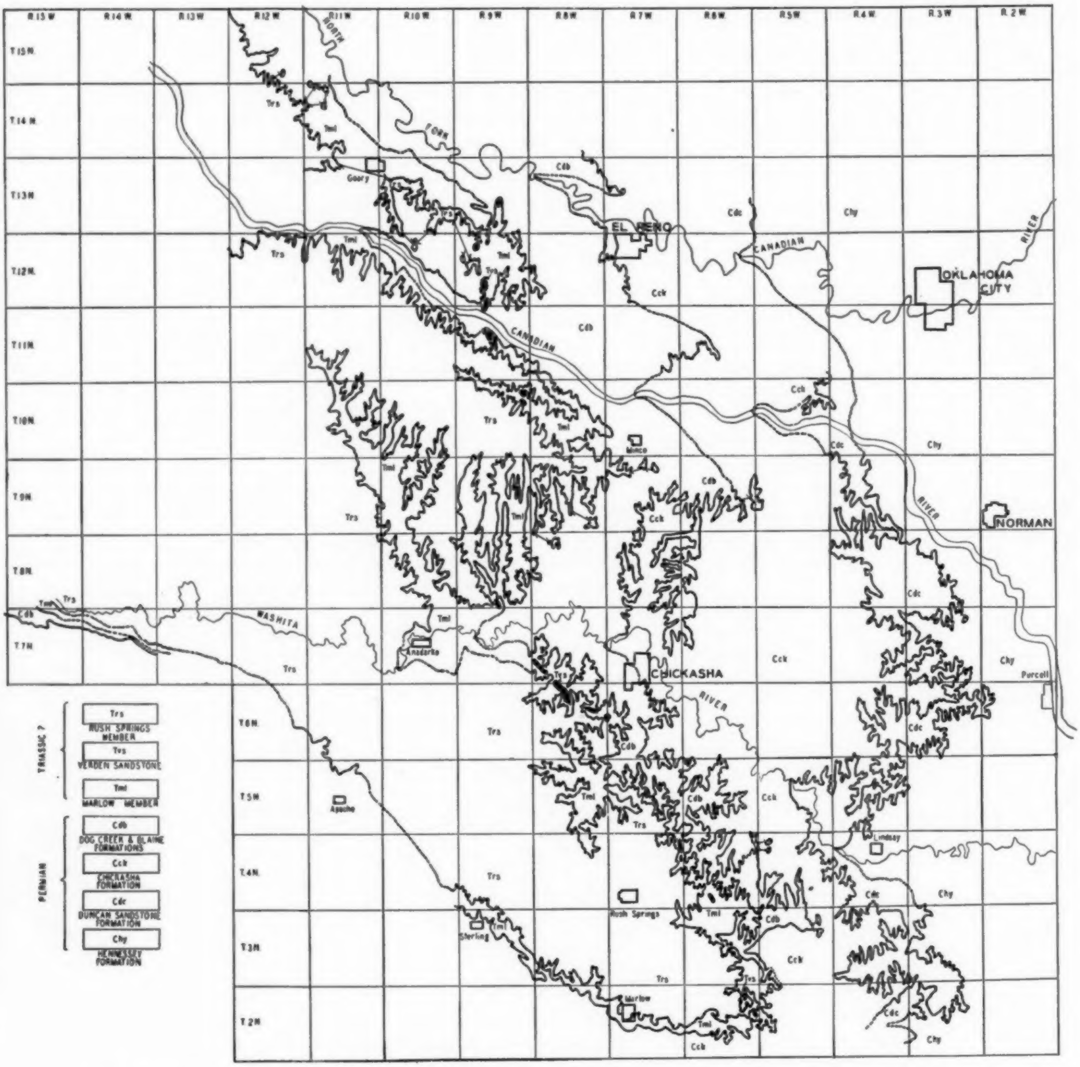


FIG. 8.—Map showing areal geology of Chickasha-El Reno region. Solid black areas are Verden sandstone.

Like the unconformity at the base of the Virgil, the unconformity at the base of the Custer increases as the distance from the Rocky Mountains decreases, except in Texas. . . . The Custer . . . occupies the same interval in Oklahoma except where the Dog Creek shales are absent, in which case the Custer may rest upon various members of the Blaine or Flower-Pot shales. Near Wildcat Mounds in Woods County, the complete removal of Dog Creek and Blaine formations prior to Custer deposition may be observed. At the southeast end of the Anadarko Basin, that is, in Grady, Stephens, and Comanche counties, it is strongly suggested that the Dog Creek and Blaine formations are non-existent due to overlap.

These citations are given as confirming the belief that an unconformity exists at the base of the Marlow member of the Whitehorse formation.

Correction in Geologic Map of Oklahoma

Accepting the contact shown between the Marlow member and the Dog Creek formation given at Greenfield, T. 15 N., R., 11 W., and following this contact southeastward into the vicinity of Sec. 18, T. 9 N., R. 8 W., the writer found the contact as outlined on the geologic map of Oklahoma at this point to rise higher in the section and eventually to outline the top of the Marlow member of the Whitehorse formation, instead of its base. This error continues southeastward from Sec. 18, T. 9 N., R. 8 W., to the axis of the Anadarko basin, thence westward. This would make a difference in the thickness of the Marlow and a horizontal difference in the position of the outcrop of 1–7 miles. The writer believes this has led to confusion and has been one of the contributing factors in perpetuating the idea of lateral gradation of Chickasha-Duncan beds into Dog Creek-Blaine farther north.

In January, 1924, a field conference included C. N. Gould, J. W. Beede, J. V. Howell, C. Don Hughes, R. W. Sawyer, F. W. Floyd, and Hugh D. Miser. The following is a brief summary of the conference relative to the area being discussed, as given by Gould.[35]

[1] Two new formations, the Duncan and the Chickasha, occupying the same stratigraphic position as the upper part of the Enid, have been added.

[2] Rocks of the same stratigraphic position carrying gypsum occur in the hills west of Minco and Pocasset, and have been traced across the region southwest of Chickasha and Ninnekah to connect with the Blaine horizon exposed near Bailey at the head of the Anadarko Basin.

[3] It [Dog Creek shale] crosses North Canadian River in the vicinity of Fort Reno and occurs in the bluffs along South Canadian River west of Union, and in the hills of northwest Grady County, west of Minco and Pocasset. It

[35] Charles N. Gould, "A New Classification of the Permian Redbeds of Southwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 3 (May–June, 1924) pp. 325, 331, 334, 335.

may be seen along the bluffs on both sides of Washita River between Verden and Andarko, where it underlies the Whitehorse sandstone which in this region occurs higher on the hills. The Dog Creek outcrops near Norge, and in the Chickasha gas field, and passes southeast a few miles east of Rush Springs, swings around the head of the Anadarko Basin, and thence continues west and northwest parallel to the other formations, at least as far as eastern Beckham County . . . In southern Grady and northern Stephens counties, the shales which constitute the Dog Creek have been referred to locally, by Sawyer and others, as the upper part of the Marlow formation.

[4] An unusual phase of the Dog Creek formation is a line of very peculiar, fossiliferous, conglomeratic sandstone exposures, which have the appearance of an old stream-channel occupying a more or less definite horizon in the upper part of the formation. This sandstone is usually spoken of locally as the "Channel sandstone," or the "Footprint sandstone," the latter name being derived from some prehistoric carvings (?) of gigantic footprints on a bowlder of this sandstone about 6 miles east of Rush Springs.

The writer agrees with conclusion No. 3, as far south as Pocasset. From this point, to where the outcrops turn westward around the south limb of the Anadarko basin, the exposures mentioned are in the Marlow member of the Whitehorse formation and not in the Dog Creek shale as indicated by Gould.

Conclusions

The writer has followed the contact between the Blaine and Chickasha formations and has found a north-south strike. The contact between the Marlow member of the Whitehorse formation and the underlying Dog Creek-Blaine formation strikes west-northwest. The Dog Creek-Blaine thins southward from 260 feet at El Reno, T. 12 N., R. 8 W., to 130 feet at Ninnekah, T. 5 N., R. 7 W. From north to south the Marlow rests successively on lower Dog Creek and Blaine members. From these facts the conclusion is drawn that an overlapping unconformity exists at the base of the Marlow member of the Whitehorse formation.

After having identified the top of the Dog Creek formation as exposed at El Reno, where it is shown on the geologic map of Oklahoma, and having followed it with plane-table mapping southwest to the axis of the Anadarko basin, the writer concludes that the geologic map of Oklahoma is wrong from Sec. 18, T. 9 N, R. 8 W., throughout the other part of the area covered in this article.

Field evidence shows that the sediments of the Duncan, Chickasha, Blaine, and Dog Creek formations grade from coarse sediments near the basin into finer sediments northward. This suggests a near source of the sediments (possibly the Arbuckle Mountains). Field evidence shows the reverse to be true of the Marlow and Rush Springs members of the Whitehorse formations.

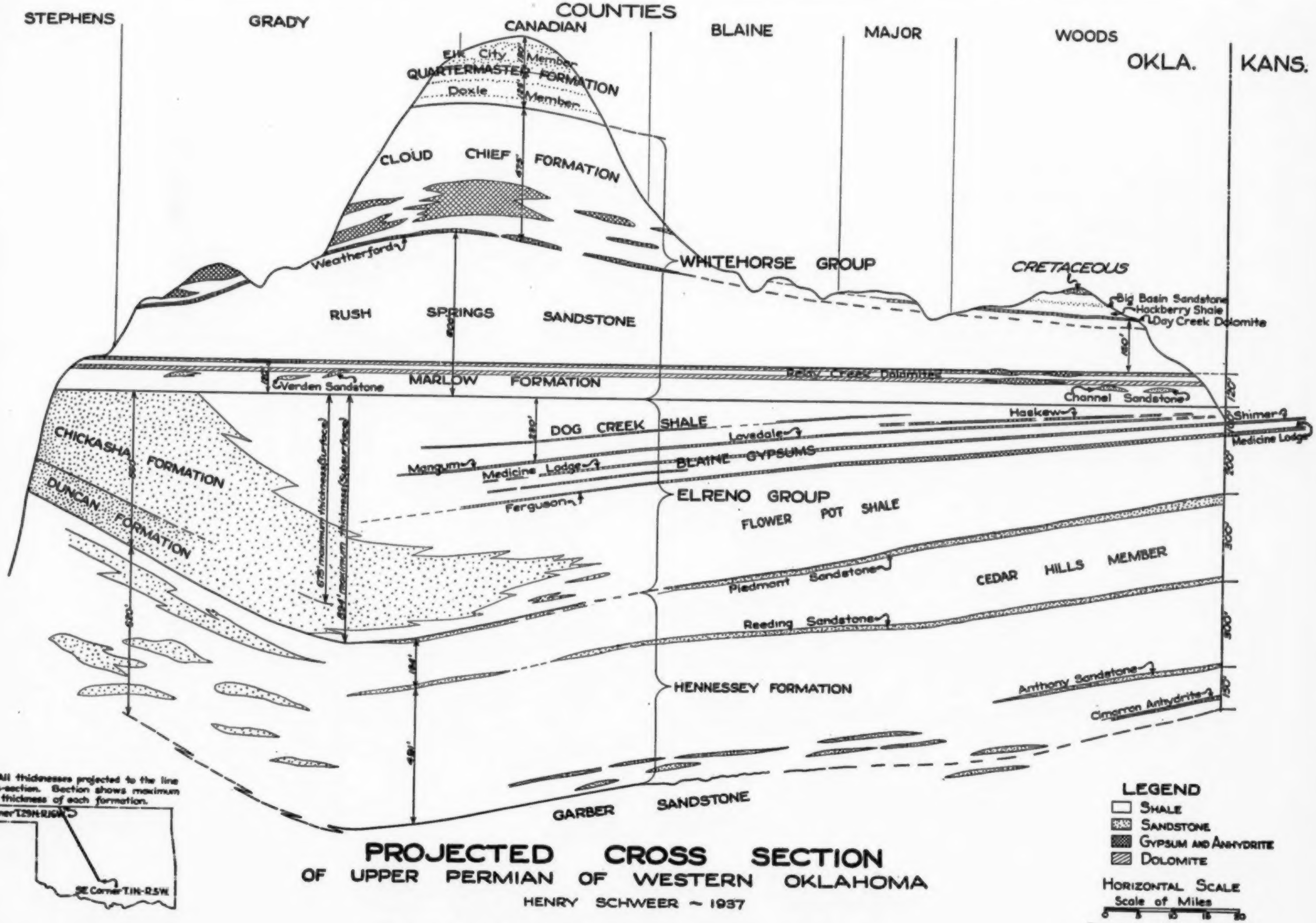


FIG. 9.—Projected cross section of Upper Permian of western Oklahoma.

In the vicinity of Greenfield, T. 15 N., R. 12 W., the Marlow is predominantly sand. East of Rush Springs the Marlow is predominantly shale. The Rush Springs member contains beds of shale in the vicinity of the town of Rush Springs. Northward, west of Greenfield, no shales were recognized. The interval between the upper Relay Creek and the lower Relay Creek, thinning from 28 feet in T. 15 N., R. 12 W., to 14 feet in T. 3 N., R. 6 W., is contrary to the rule that all Permian formations thicken southward, and since an unconformity of wide extent is present at the base of the Marlow member of the Whitehorse formation, it is believed that the Whitehorse formation might well be Triassic rather than Permian.

DISCUSSION

HENRY SCHWEER, Tyler, Texas (written discussion received, July 1, 1937): Mr. Brown has given us an interesting conception of sedimentation near the head of the Anadarko basin. However, a different interpretation has been placed on units within the El Reno group by many geologists who have done extensive detailed work in the area. While the writer has the highest regard for Mr. Brown's work, he believes it pertinent that another interpretation be pointed out at this time, namely, *lateral gradation* as opposed to "overlapping unconformity."

The term "El Reno group" was applied in 1928 to that group of formations occupying the interval from the base of the Duncan sandstone to the base of the Marlow member of the Whitehorse.[36] In and near the head of the Anadarko basin the formations comprising the El Reno group are coarse, cross-bedded clastics. This type of formation resulted from deltaic and semi-terrestrial deposition of material coming from the southeast. Rapid deposition resulted in much cross-bedding with no sorting of materials near the head of the basin, whereas farther north and west (basinward) the finer materials were more easily transported, and still farther from the clastic source, very fine clastics and precipitates were deposited, Flower-pot shale, Blaine gypsums and dolomites, and Dog Creek shale. Consequently these even-bedded members of the El Reno group are basin (quiet-water deposition) facies of the same age as the coarse, cross-bedded Duncan-Chickasha facies nearer the source.

At the Kansas line the Dog Creek formation has a thickness of 45 feet, this being the interval between the top of the Blaine and the base of the Marlow. Southward this interval increases until the Dog Creek attains a thickness of 230 feet west of El Reno, Canadian County. This thickness is given by Brown as 260 feet, so we are fairly closely agreed at this point. However, Brown considers the dolomite exposed at the west edge of El Reno to be basal Blaine. The writer mapped by plane-table detail the Blaine section from the type locality in Blaine County to the area south of El Reno, using all members of the Blaine for control, and the fossiliferous bed cropping out on the south edge of the El Reno Country Club is definitely the top bed of

[36] The Whitehorse at that time was known as a "formation," but has since been elevated, by almost unanimous consent of geologists familiar with the area, to the rank of "group."

the Blaine. The lower beds have graded to clastic materials and do not extend as far south (in the form of precipitates) as does the top bed. Some few miles farther south this dolomite loses its dolomitic character and the entire Blaine section has then graded southward into the clastic Chickasha. This transition is toward the source and toward the head of the basin. The same general change of facies holds true for the Flower-pot shale, below the Blaine, and the Dog Creek shale above; they grade southward from even-bedded nearly pure shale into the cross-bedded Duncan-Chickasha. This gradation was the reason for combining these facies units into the "El Reno" group. The basal contact of the El Reno with the Cedar Hills-Hennessey and the upper contact with the Marlow are chronologic horizons that can be carried from Kansas to Texas.

This same condition of lateral gradation can be observed northwestward from the head of the basin along the north side of the Wichita Mountains. As the distance from the source increases, the sediments of the El Reno group become finer until the Blaine appears as a precipitate. The Wichita Mountains contributed nothing to this part of the section, as they were covered by the El Reno sea.

The close of El Reno time was sudden, probably resulting from submergence of the area southeastward from which El Reno (Chickasha-Duncan) sediments were derived along with the submergence of all near-by areas which had been at or near sea-level. The Marlow (initial Whitehorse) sea then spread out over an extensive region, completely covering with shallow quiet water the area near the head of the Anadarko basin.

It is granted that this resulted in a small unconformity between the Marlow and the El Reno, but the marked difference of type of sediments is due to marine deposition on beds deposited as deltaic or terrestrial, and not to uplift and erosion as indicated by Brown's cross section.

Brown's work is a distinct contribution and it is to be hoped that more students of the area will find time and patience to report on this interesting section of the Oklahoma Permian.

HASTINGS MOORE, Longview, Texas (manuscript received, July 1, 1937): Mr. Brown, referring to his Figure 4, states that converging contours based on mapping beds on the Marlow in one area and on the Chickasha-Blaine contact in an adjacent area, demonstrates overlap of the Marlow member. With this I agree fully if it is admitted that the Chickasha-Blaine contact occupies a continuous stratigraphic position.

As long ago as 1927 the writer and many other geologists working on the south flank of the Anadarko basin, determined to their full satisfaction that the Chickasha-Blaine contact did not represent a stratigraphic horizon, but essentially a lithologic change caused by lateral gradation westward of the coarse cross-bedded Chickasha and Duncan members into the evenly bedded shales, gypsum, and gypsiferous shales of the Dog Creek-Blaine members. I speak of the Blaine and Dog Creek and Chickasha and Duncan as members of what Buckstaff, Schweer, and Moore named the El Reno group, which covers the formations occupying the position above the Hennessey shale and below the Marlow member of the Whitehorse formation.

Certain it is that the thickness of the El Reno group, as so defined, remains constant from the head of the Anadarko basin near the town of Marlow in northern Stephens County, northwestward, following its exposure along the

south flank of the Anadarko basin for a distance of at least 75 miles to the town of Rocky in southern Washita County.

Immediately south of the town of Carnegie where the entire El Reno group, as previously defined, crops out within a distance of 2 miles, there is a complete absence of the Chickasha member and the Duncan member is only about 25 feet thick. The Dog Creek-Blaine members have thickened exactly the same amount as the Duncan and Chickasha members have thinned from their point of maximum development at the head of the basin in Stephens County.

Mr. Brown's cross section along the east flank of the basin shows a full section of a Chickasha "formation" beneath the Dog Creek and Blaine "formations." If this section is correct for the east flank of the basin, it is in absolute contrast with conditions on the south flank.

All of Mr. Brown's observations, so far as revealed by his manuscript, were made on the east flank of the basin and unfortunately my field of work was confined to the south flank of the basin. However, I have been informed by many competent field men, including Buckstaff and Schweer, that the Chickasha member grades laterally northward into the Dog Creek-Blaine and Flower-pot members of the El Reno group.

Might I suggest that as the El Reno group is exposed in a much narrower band areally, due to steeper dips on the south flank of the Anadarko basin, it is subject to more comprehensive study in that area?

Anyone seeking to determine the proper inter-relation of the members of the El Reno group must, in my opinion, give careful study to the conditions as found on the south flank of the basin.

Four years of intermittent study of the south flank of the basin left me entirely without evidence of unconformity or overlap, between the Marlow member of the Whitehorse formation and the underlying El Reno group. On the contrary, it developed positive mathematical proof that the Chickasha and Duncan members graded laterally northwestward into the Dog Creek and Blaine members.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 12 (DECEMBER, 1937), PP. 1557-1558

LOWER RED-BEDS OF KANSAS[1]

GEORGE H. NORTON[2]
Wichita, Kansas

The lower Red-Beds are well exposed in Kansas where Cragin named the beds here considered, which are classified in his Salt Fork division of the Cimarron series, Permian system, as follows: Harper sandstones, Salt Plain measures, Cedar Hills sandstones, Flower-pot shales, Cave Creek formation, and Dog Creek shales.

The Harper sandstones lie conformably on the Milan limestone member at the top of the Wellington shales. The formation is readily divided into 4 members, here named for their type exposures in Kansas, in ascending order: Ninnescah shale member, Stone Corral member (an evaporite deposit), Chikaskia sandstone member, and Kingman sandstone member.

Close to the Oklahoma line, the lower three-fourths of the Ninnescah shale, which totals 290–390 feet, grade irregularly and rapidly into the cross-bedded sandstones and conglomerates of the deltaic Garber of Oklahoma.

The prominent salt-anhydrite-dolomite series of the subsurface due to solution of ground waters, is reduced at the surface outcrop to a massive 6-foot ledge of cellular dolomite which splits and loses character southward, but is recognizable as dolomitic streaks and huge dolomite-crusted halite casts in the irregularly bedded sands into which it merges. This Stone Corral member appears to lie unconformably on various beds of the underlying Ninnescah. There is also evidence of unconformity, complicated with solution brecciation, immediately above the Stone Corral.

The Chikaskia member, 100–125 feet thick, is marked by many benches of red sandstone separated by red and gray shales and containing numerous geoidal sugary-dolomite concretionary lentils.

The Kingman sandstone member is an 80-foot unit of silty red sandstone containing a 3-foot white sandstone at its base, which is a prominent marker throughout the exposure of the Harper. The member is readily carved by youthful streams into canyon topography. The top is not distinct, but is placed arbitrarily at a bed of maroon shale.

[1] Manuscript received, July 27, 1937. This is an abstract of the complete manuscript which will be published in a later *Bulletin*.

[2] Atlantic Refining Company.

The Salt Plain measures, due to the soft character of their flaky, silty shales, and some included salt and anhydrite, are well exposed in limited areas. They include thin soft red sandstone benches near the base, some fissile shaly beds, and in the upper part, two heavy sandstone beds. The lower shows extreme cross-bedding and irregularity of deposition, indicating proximity to another Oklahoma delta, at this stratigraphic position. The member is 273–290 feet thick.

The Cedar Hills sandstone resembles the Kingman in color and character, weathers to promontories and canyons, and contains a prominent white bed at the base. It is 180 feet thick and a thinner white sandstone with "snow-ball" concretions of gypsum marks the top.

The Flower-pot shales are red and criss-crossed with veins of selenite and are broken by a few gypsiferous sandstone benches, and here and there a discontinuous dolomite lentil. Locally a bed of red sand is reported near the base of the member. The thickness is approximately 190 feet.

The Cave Creek formation consists of the Medicine Lodge gypsum, Jenkins shale, and Shimer gypsum, totalling about 50 feet. Solution at the surface has made many sections appear irregular, since the gypsum beds vary in thickness.

Overlying the gypsum beds are similar strata with thin dolomites or sandstone such as underlie the gypsums of the Cave Creek, bedded in red shale, from which the once-present gypsums have been removed by solution. These have been called the Dog Creek shales, but are generally recognized as closely related to the underlying beds. Their thickness ranges from 5 to 23 feet. They are overlain, with disconformity, by coarse red sandstone of the Whitehorse, originally called "Red Bluff" by Cragin. A major break in the section is recognized here, and marks the base of the Kiger division of the Cimarron series.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 12 (DECEMBER, 1937), PP. 1559-1572

DISCUSSIONS AT PERMIAN CONFERENCE NORMAN, OKLAHOMA MAY 8, 1937[1]

SUBMITTED TO AUTHORS AND SUBSEQUENTLY CORRECTED

EDITED BY ROBERT H. DOTT[2]
Norman, Oklahoma

H. L. GRILEY:[3] An unconformity may vary in time and place. Philip B. King, in writing about the Permian, has said: "Orogenic movements are confined to certain mobile regions, and in some regions near by there is likely to be nearly continuous sedimentation. The movements are pulsatory . . . and the greatest pulsation in one area may not be at the same time as that in another."[4]

Our areas of Pennsylvanian and Permian deposition have been described as flat basins. Local variations in sedimentation have been observed in Illinois and elsewhere in a study of cyclothems. There is much evidence to support the idea that in the Anadarko basin of Oklahoma, subsidence of the sea floor was just about equal to accumulation of sediment. Relatively steep dips in the Permian along the north side of the Wichita Mountains can best be explained by subsidence of the neighboring deeper part of the basin, not underlain by competent rocks of the mountains.

In Oklahoma, shallow-water conditions prevailed during most of Permian time. Mudstone conglomerates are common in the Stillwater and Wellington formations; salt crystals developed on mud flats during Flower-pot and Dog Creek time. In the Chickasha facies of the Flower-pot, truncated prism-shaped masses, standing at odd angles, indicate turbulent shallow-water conditions. Under sedimentary conditions of this type, a slight elevation of an area of a few square miles would create local unconformity, of such limited extent that any reference to unconformity should include section, township and range, or other specific location.

CHARLES N. GOULD:[5] I used to get excited about unconformities in the Red-Beds, but have learned that it is all unconformity. I used to think that Permian formations were continuous for long distances, but we now know they are mostly interfingered. Roy Wilson[6] said in effect that Permian sediments were derived from streams rising at the north, east, and south, depositing their loads of sediments into a southwestward-retreating sea.

[1] Manuscript received, July 24, 1937.

[2] Director, Oklahoma Geological Survey.

[3] Published with permission of Sun Oil Company.

[4] Philip B. King, "Permian Stratigraphy of Trans-Pecos Texas," *Bull. Geol. Soc. America*, Vol. 45 (1934), p. 706.

[5] National Park Service.

[6] Charles N. Gould and Roy A. Wilson, "The Upper Paleozoic Rocks of Oklahoma," *Oklahoma Geol. Survey Bull. 41* (1927), p. 44.

DARSIE A. GREEN:[7] The deltaic facies represent a series of local unconformities. Every time a shore line was lifted and its delta shifted farther toward the basin, a local unconformity was formed. These local unconformities caused the shoreward sections to be shorter than the basinward sections. Consequently, intervals in wells drilled in the Oklahoma City field are much longer than those measured along the surface from Oklahoma City to outcrops in Seminole County.

IS THERE AN UNCONFORMITY AT BASE OF WHITEHORSE (MARLOW)?

VAUGHN W. RUSSOM[8] attempted to crystallize opinion regarding an unconformity at the base of the Marlow, by asking the views of various workers, who responded as follows.

HENRY SCHWEER: I do not think there is an unconformity at the base of the Marlow, but that the observed conditions which suggest unconformity to others are the result of lateral gradation, and that the beds below the Marlow are parallel with it. With an unconformity at its base, the formation should thicken, at least locally, to fill in pre-existing depressions, whereas, if the Marlow is traced over a wide area, it has a definite thickness of 120 feet throughout a distance of more than 100 miles.

GRILEY (written discussion): In regard to the Dog Creek-Whitehorse contact (base of Marlow) in general, I believe that throughout a part of the area there is local unconformity, such as might occur under deltaic conditions, by temporary strengthening of the current in outlets forming an estuary of a large river. That such unconformity is local is indicated by the fact that the reworked material is principally that transported very short distances. Angular blocks of gypsum were observed which seemed to have been derived from beds that normally occur near the Dog Creek-Whitehorse contact. Parts of the contact intermediate to those where reworked material is present show no direct evidence of a break in sedimentation. There is no evidence of even local unconformity at the base of the Whitehorse in northwestern Oklahoma, but such unconformity is common in the extreme southwestern part of the state.

In the area northeast of Woodward a sandstone, about 8 feet thick, is present in the upper part of the Dog Creek which, being lithologically like the Whitehorse, seems to indicate a gradation in sediments, and not a sharp break or unconformity.

The study made by Bass, which shows that the Verden sandstone originated as an off-shore bar, should be used in picturing conditions which were present in Oklahoma during Whitehorse time.

The changes which occur laterally within the Whitehorse deserve consideration. In the area south of Chickasha the Marlow is very shaly; and such sandstones as it contains in that part of Oklahoma are very definite ledges. Those sediments accumulated in relatively quiet, relatively deep water. Westward in Oklahoma the Marlow becomes a unit composed almost entirely of cross-bedded sandstone. While this change occurs in the Marlow,

[7] Pure Oil Company.

[8] Sinclair Prairie Oil Company.

a change in the opposite direction, that is from cross-bedded sandstone to shaly sediments, occurs in the overlying Rush Springs. The Rush Springs is so shaly north of Amarillo that for years it was called Quartermaster. In that part of the outcrop where the Marlow is shaly and marine in type there is little or no evidence of unconformity at its base. These bits of information should be used in locating the area from which the sediment was derived and part of the problem of unconformity would be solved, since unconformity would be more prevalent near the land mass than basinward.

OTTO E. BROWN:[9] There is a widespread unconformity. It may be local, but several authors have observed it over wide areas. It is of sufficient magnitude to cut out a full section of the Dog Creek. I do not agree that the Dog Creek grades into the Chickasha. The Blaine can be identified as far south as these formations are exposed.

SCHWEER (written discussion): If the Blaine is traced south from its type locality, it will be observed that it entirely loses its evaporite character a few miles south of El Reno, where the entire Blaine has graded into clastics of the Chickasha formation. Apparently, Mr. Brown has picked up some gypsum bed farther south that is much higher in the section, and near the top of the Chickasha, and has correlated this with the Blaine.

RUSSOM:[10] Wedel, Green, Lehman, Brown, and I have worked in the Anadarko basin, and all agree that there is a definite and widespread break at the base of the Marlow. Brown's contours in T. 6–7 N., R. 7 W., on the Marlow and on beds below intersect at a decided angle, proving conclusively that an unconformity exists.

(Written discussion): One of the most convincing proofs of this unconformity can be seen in the vicinity of the Cruce anticline in Stephens County. The forces which caused the folding of the Velma-Cruce anticline pushed the escarpment of the Duncan sandstone several miles farther north than it would normally be. This is shown on the geologic map of Oklahoma.[11] However, if the base of the Marlow is mapped eastward from the town of Marlow and north of the north end of the Cruce anticline, it is found to continue eastward unaffected by the Cruce anticline. This means that the age of the folding is post-Duncan-Chickasha and pre-Marlow, else the Marlow beds would be pushed north in agreement with the Duncan.

Here was post-Duncan structural movement and deep erosion before the Marlow was laid down. Furthermore, at the north end of the Cruce anticline the outcrop of the base of the Duncan is less than 2 miles from the base of the Marlow, and less than 200 feet of intervening rocks separate them, whereas at the town of Duncan and northward, the outcrops of these two horizons are 7 miles apart, and at least 600–700 feet of rocks intervene between them. This stratigraphic interval decreases to approximately 350 feet farther west.

This opportunity is taken to commend the work of Roger W. Sawyer.[12]

[9] Published with permission of the Gulf Oil Corporation.

[10] Published with permission of Sinclair Prairie Oil Company.

[11] Hugh D. Miser, *Geologic Map of Oklahoma* (U. S. Geol. Survey, 1926).

[12] Roger W. Sawyer, "Areal Geology of a Part of Southwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8 (1924), pp. 312–21.

It was he who really straightened out the geology of the Anadarko basin and published an accurate map to show this geology. He correctly placed the Duncan (now of Green), Blaine, Dog Creek, and Marlow formations in the geologic section. He named the Marlow formation and proved that it was definitely above the Blaine, and that the true Blaine does not go entirely around the head of the Anadarko basin as believed by some, and that beds formerly considered as being Blaine in this area belong to the Marlow formation. With a few exceptions, all geologists who have had opportunity to check this section have corroborated the work of Sawyer.

The Marlow formation is proving to be a stratigraphic unit of regional importance. D. A. Green has observed what he considers Marlow in southwestern Barber County, Kansas, and Robert Roth maps it in Texas. The writer wishes to go on record as saying that he knows of no geological formation or member of a formation, that is more entitled to recognition than the Marlow formation of Roger W. Sawyer.

Roy P. Lehman:[13] I believe there is a large unconformity at the base of the Marlow. In preparing structure contour maps, it is evident there is an unconformity, cutting out beds in the area south of Canadian River. About 400 feet of sediments have been cut out over the Cruce anticline, and a like amount over the Carter-Knox fold.

Schweer (written discussion): The local area of the Cruce anticline has been cited repeatedly as the basis for postulating a widespread unconformity at the base of the Marlow. After all, this anticline covers only a small area, and is one of the most pronounced structures in the region under discussion. A broader concept of the region should be applied. Furthermore, the steep dips off the Cruce anticline tend to give smaller intervals between the base of the Duncan and the base of the Marlow than actually exist. Also, the stratigraphy of the intervening beds makes the measurement of this interval difficult, and changes in dip further complicate accurate measurements. Just how much of the upper Chickasha section is cut out, and how much of the decreased section is due to lateral thinning onto the "high" is almost impossible to determine.

Arthur Wedel[14] (written discussion): I agree with Mr. Schweer that the Marlow has a uniform thickness and that there is no channeling at the base, but I do not consider that these facts prove the absence of unconformity. From personal observations I am convinced that an unconformity is present at the base of the Marlow, that the Marlow is not parallel with pre-Marlow sediments in any of the area which I have mapped and observed, and that the Marlow is very close to the base of the Duncan sandstone over pre-Marlow folds like the Cruce and Carter-Knox anticlines.

Uniformity of thickness of the Marlow and absence of channeling at its base simply mean that the old eroded pre-Marlow surface had been worn smooth, and that the currents which brought in the fine Marlow sediments and deposited them so evenly, produced no scouring action.

In my opinion, the course of events from the beginning of Duncan time to the present, was as follows.

[13] Published with permission of Phillips Petroleum Company.

[14] Published with permission of The Pure Oil Company.

1. Continuous deposition of Duncan, Blaine, Dog Creek, and possibly younger beds, in the succession named, on a gently subsiding, somewhat even sea bottom.

2. A stage of pronounced warping of the sea floor at some period between Dog Creek time and Marlow time. One of the structural changes which occurred during this period was a slight northwestward tilt of the area now occupied by the southeast end of the Anadarko basin, as evidenced by the fact that the Dog Creek-Blaine formations are partly or wholly lapped out by the Marlow in this area. Another set of occurrences was the actual greater or less pronounced folding of the beds on the southwest side of the basin, exemplified by the Cruce and the Carter-Knox anticlines.

3. A partly contemporaneous and partly subsequent levelling-off of the uneven surface produced by the warping, as evidenced by the fact that the Marlow was deposited with uniform thickness and striking parallelism, on the surface beneath it. Whether this levelling process was one of peneplanation of an uplifted land surface, or took place entirely under water, I shall not attempt to say, although the latter alternative would be the more difficult to conceive.

4. Gentle subsidence of the levelled surface, and deposition of Marlow by quiet currents in a very quiet lake or sea, as evidenced by the nature of the Marlow sediments. Continued deposition of sediments to the end of Permian or Triassic. Of the post-Permian-Triassic deposition we have no record, in this immediate area.

5. Contemporaneous and subsequent tilting of the two sides of the Anadarko basin to form that basin, warping which caused the surface folds of the Cement anticline and other post-Marlow folds, and rejuvenations.

SCHWEER (written discussion): In his sub-head 5, Mr. Wedel states: "Subsequent tilting of the two sides of the Anadarko basin to form that basin . . . " He has completely failed to observe the fundamental concept of Anadarko basin deposition, namely, that the basin was continually sinking while being loaded with sediment, this depressing influence gradually decreasing away from the axis of the basin. Failure to observe this naturally leads to a minimizing of the importance of lateral gradation, and leads to the postulation of "extensive unconformity" as an explanation of the various depositional phenomena.

GRILEY: The Dog Creek formation, except where developed as a clastic facies near Chickasha and south of that town, is readily divisible into units or members. The increase in thickness southward in Oklahoma is by units and not by changes at its top through truncation. Sedimentary gradations in the Marlow affecting its content of shale, sandstone, and gypsum are largely regional, but to some extent local. Roth has recently described some of these local variations which can be observed in or near Childress County, Texas.

The Marlow has everywhere a uniform thickness of about 120 feet. It has this thickness near Bailey, a town northeast of Marlow. Its base is a definite stratigraphic horizon. Near Bailey the formation which underlies the Marlow is the purple arkosic sandstone which Clyde Becker made part of his El Reno group, explaining that by gradation and facies change the El Reno is undifferentiated Duncan, Chickasha, Blaine, and Dog Creek. There

is general agreement among field geologists that there was this facies change to clastic sediment shoreward onto the west end of the Arbuckle Mountains. Green and Brown, and possibly other men, support the idea that in the area closer to the mountains than that in which facies change took place, there is also angular unconformity, and overlap at the base of the Marlow.

Figures once given me as those obtained in core-drilling near Cement show that the interval there from the base of the Marlow to the base of the Duncan is about 625 feet. This interval would be ample to include a clastic phase of the Blaine and Dog Creek and indicate that overlap by the Whitehorse in that locality is improbable.

Measurements made by Green, Schweer, and others in the area east of the town of Marlow show that the section of rock between the base of the Whitehorse and the base of the Duncan (Becker's El Reno group) has a thickness of only about 400 feet at that point. The diminished thickness might as readily be attributed to shoreward thinning onto the Arbuckle Mountains as to angular unconformity and overlap.

Evidence in support of, or against the idea that there is truncation of the Dog Creek and Blaine, with overlapping Whitehorse, in southern Grady County, must come largely from attempts to trace recognizable zones and beds in the outcrops. Some students of the problem are not yet convinced that such tracing of stratigraphic lines is possible with any considerable degree of certainty in that area of marked facies change.

Darsie Green and Otto Brown are men who have had years of experience in mapping Permian formations. Their work and their decisions in connection with this problem should stand as probably correct, or at least so stand until equally formidable evidence to the contrary is presented.

Considered from a regional viewpoint, the presence of angular unconformity in southern Grady County at the base of the Whitehorse is not at all unnatural.

Unconformity Versus Disconformity

Considerable discussion was forthcoming as to exactly what constitutes an unconformity. Some speakers contended that marked angularity or discordance in dip, a deeply eroded under-surface, conglomerate, and similar phenomena are necessary; others contended that many important time breaks are very inconspicuous, yet must be considered unconformities.

Wedel (written discussion): I have not mapped the formations ranging from Duncan through Marlow in age throughout as wide an area as some others. To be specific, I mapped these formations from the meridian of Cruce as far northwest as Mountain View, a distance of 60 miles along the south side of the Anadarko basin. I am convinced that there is an unconformity at the base of the Marlow throughout this extent, and one so widespread can hardly be called local. The statement has been made that the intervals between the beds in the Marlow, including the base, and mappable horizons below in the Dog Creek are too constant to permit the possibility of an unconformity.

On the south side of the basin from Cruce to Carnegie the only mappable beds between the base of the Marlow and the base of the Duncan are the lower

150 feet of the Duncan formation, if we except the base and top of the arkosic conglomerate referred to in Mr. Green's paper. The interval between beds in the Marlow and these mappable beds in the basal Duncan is certainly an extremely varying one throughout this area, ranging from at least 600 feet immediately north of Duncan to 150 feet or less north of Cruce. On the north side of the basin, in the Chickasha area, as Green and Brown have shown, the top of the Duncan or Chickasha-Duncan certainly does not maintain a constant interval with respect to the base of the Marlow.

I am aware, of course, that this condition is explained as being only an apparent shortening of interval—that the alleged top of the Chickasha-Duncan is not a true stratigraphic horizon, but is the top of a delta sand deposit which, because of progressively receding sand fingers in later Chickasha time, transgresses the section downward toward the northwest. I consider this conclusion unwarranted, because if the bed in question were actually the top of a delta which was thus receding, there would be great interfingering of sands with shale and a very irregular contact of Blaine on Chickasha, whereas the bed when mapped is seen to have a nearly uniform surface.

Furthermore, if I understand Mr. Brown correctly, he did not actually map on the top of the cross-bedded Chickasha sandstone, but rather on a persistent, white, somewhat indurated silt-stone bed in the Blaine shale a short distance above the contact. I have observed the bed in question in the field, and have no doubt that it is a true persistent stratigraphic horizon.

I do not doubt the statements of those who disclaim the existence of an unconformity, that in much of the area where they have mapped Marlow and pre-Marlow beds, the intervals between the two sets of beds does not vary appreciably, but I agree with Green that we may have such constancy of intervals throughout a wide area even between beds on two sides of a great hiatus. The unconformity in this case would be called a disconformity. Of course, it may also be true that in those areas there was no interruption of deposition, or removal of sediments by erosion, between Marlow time and pre-Marlow time. In making a claim for an unconformity at the base of the Marlow, I can be sure only of the area mapped by myself, and the one in the Chickasha area covered in Mr. Brown's paper.

Schweer (written discussion): Mr. Wedel states "... the top of the Duncan or Chickasha-Duncan certainly does not maintain a constant interval with respect to the base of the Marlow." Apparently there is some confusion here as to stratigraphic names, in that the top of the Duncan-Chickasha is *in contact* with the base of the Marlow. He also states "... it may also be true that in those areas there was no interruption of deposition, or removal of sediments by erosion, between Marlow time and pre-Marlow time," thereby refuting the previous statements as to widespread unconformity.

Brown: I took a group of geologists over the area I worked, and showed them the top of the Chickasha. It can be followed for a considerable distance. I think practically all of the Dog Creek and Blaine is cut out by unconformity in T. 2 N., R. 6 W.

Schweer: According to my conception, an unconformity is a part of a cycle. After sedimentation with submergence there occurred emergence, resulting in beds having different angles of dip. Cessation of deposition is dis-

conformity. I believe that deposition ceased at the top of the El Reno (top Dog Creek), different currents wandering over a shallow sea, and the Marlow sandstone was deposited over the whole area.

BROWN: The pre-Marlow folding of the Chickasha-Duncan beds shows angular unconformity over the Carter-Knox anticline in T. 3 N., R. 5 W.

ROBERT ROTH:[15] There are several points concerning the unconformity at the base of the Custer group (base of Marlow) which are, perhaps, not usually considered in the field. The Mid-Continent region has not suffered orogeny from the beginning of Permian time to the Recent except locally; that is, in the regions of the Arbuckle and Wichita Mountains. Epeirogeny, or continental uplift of a wide area, did occur at the base of the Custer group. This type of uplift does not produce an angular unconformity, but the change of environment is evidenced by a marked change in the type and character of the sediments. The most important evidence of the unconformity is the character of the sand grains themselves. In the Permian below the Custer group the sand grains are all angular. On the other hand, the sand grains of the Custer group are all rounded and polished and are of an orange or vermilion color. These sand grains are eolian in nature and do not have the physical aspects of the underlying Permian sands. The presence of fossil sand dunes in the Custer group substantiates the eolian nature of the sand grains. The only other occurrence of wind-blown sands in the Mid-Continent is in the St. Peter of Ordovician age and its lateral equivalents.

GEORGE H. NORTON (written discussion): Personally I enjoy Mr. Roth's ideas and think the evidence he presents is helpful, but from my experience in the Kansas area, in the Southard and Mangum areas in Oklahoma, the Acme, Childress, Aspermont, Hamlin, Rotan, Longworth, and Sweetwater areas in Texas, in my observation of the same outcrops, I have failed to arrive at the same conclusion. While working 5 years for the United States Gypsum Company, during an expansion period, I saw most of the commercial gypsum deposits of the continent. Perhaps that is why I prefer gypsums, dolomites, and anhydrites as horizon markers to the drifting dunes of orange-polished sandstones ranging from Cedar Hills or Salt Plains to the top of the Permian.

BLAINE FORMATION

RUSSOM (written discussion): In Secs. 19, 20, 28, and 29, T. 7 N., R. 13 W. the Blaine beds are well developed. The fossiliferous dolomite is 42 feet below the upper dolomite, according to the writer's measurements. Above the upper dolomite are 3 feet of maroon shale, followed by 1–6 feet of typical gypsum. The easternmost point at which the fossiliferous dolomite was found is 1,300 feet east of the SW. corner of the NW. ¼, Sec. 28, T. 7 N., R. 13 W. By projecting dip the writer estimates 130 feet of sediments between the highest gypsum of the Blaine and the base of the Marlow. This is probably mostly Dog Creek, although some of it could be of Blaine facies. In a distance of 800 feet the Blaine beds dip 70 feet toward the northeast. About 330 feet of so-called Chickasha beds intervene between the fossiliferous dolomite and the highest bed of the Duncan in Secs. 30 and 31. In almost every exposure in

[15] Published by permission of the Humble Oil and Refining Company.

this township and as far east as the Apache area, the base of the Marlow rests on maroon shale containing white bands. Southeastward exposures of this type become scarcer and southeast of Fletcher the base of the Marlow rests on the cross-bedded sandstones and mudstones of the Chickasha formation. This condition exists around the head of the Anadarko basin and perhaps farther north.

The Blaine beds south of Carnegie apparently grade into the Chickasha, and the Dog Creek beds either do the same, or else the base of the Marlow rests on successively lower horizons in the Dog Creek, until all the Dog Creek has been cut out by overlap of the Marlow.

In the Carnegie area the total thickness of strata from the highest Duncan bed to the base of the Marlow is about 500 feet. Between Duncan and Marlow this interval is possibly 600 or 700 feet. It seems there may be both lateral gradation and overlap.

Verden Sandstone

Roth: The Verden channel sandstone has been referred to by many as a type of marine deposition. I have seen pebbles several inches in diameter in this conglomerate. It is difficult to conceive of a marine current having sufficient velocity to transport this material.

Leland W. Jones: Where can you see gravel in the Verden Channel sandstone of the size you describe?

Roth: The Wildcat Buttes for one place.

Brown: What is the Verden sandstone?

Roth: I believe it is a beach deposit.

Brown: The Verden sandstone thins and thickens at the expense of the shale interval in which it is deposited. It also is at a very definite stratigraphic line in the Marlow, above a definite white sandstone. The Verden sandstone dips from an elevation of 1,550 feet in the area around Calumet to an elevation of 1,250 feet in the area around Chickasha. I believe the Verden is a barrier beach.

Green: The problem of the Verden sandstone is very well covered by N. W. Bass in a paper read at the meeting of the American Association of Petroleum Geologists, in Los Angeles, in March, 1937.

Other Unconformities

Russom (written discussion): There has been some intimation that an unconformity exists at the contact of the Marlow and Rush Springs members of the Whitehorse formation. The writer concurs with Brown in considering that none exists at this horizon. Certainly there can not be one of much magnitude. The intervals between the upper Relay Creek dolomite and the pink shale below, and the upper pink shale (the lowest mappable bed in the Rush Springs), are too constant to permit any angular unconformity, and a study of the sediments does not encourage the belief that a disconformity exists.

The writer hopes that the terms Marlow and Rush Springs will be generally accepted, and that the contact between them will be placed at the top

of the upper Relay Creek dolomite, and not 10 or 15 feet higher as some have suggested. Many geologists already place the contact at this bed, and it would seem undesirable to fix it at an indefinite horizon when such a good bed is available. We now know that the top of the Marlow should be higher than Sawyer put it.

The maximum thickness measured by the writer for the Marlow beds, from the base of the formation to the top of the upper Relay Creek dolomite (Evans), is 137 feet in Ts. 3 and 4 N., R. 9 W., near Sterling. It is 103 feet thick in T. 2 N., R. 7 W., at Marlow, and 100 feet in T. 6 N., Rs. 11 and 12 W., and in T. 7 N., Rs. 12 and 13 W. Measurements are difficult to obtain in T. 7 N., R. 13 W., but 100 feet is probably approximately correct. Other intervals vary within these limits. In T. 7 N., R. 13 W., the upper Marlow beds are poorly developed. The only exposure where the pink shale can be found associated with the upper Relay Creek dolomite is in Section 23. The dolomite alone has not been seen by the writer farther west than the northwest part of Section 16 of the same township.

LEHMAN (written discussion): The extent and prominence of an unconformity at the base of the Cloud Chief is difficult to determine. However, field data would indicate that such an unconformity exists at least in certain areas. About 3 miles north and a little west of Rush Springs, in Sec. 18, T. 4 N., R. 7 W., is a small outlier of Cloud Chief gypsum, in the syncline east of the Chickasha anticline, and about 1½ miles south of this, in Sec. 30, T. 4 N., R. 7 W., is another occurrence of Cloud Chief.

The thickness of the Rush Springs member of the Whitehorse formation in the northern exposure is approximately 270 feet, and in the southern, approximately 210 feet. This change is in a distance of 1½–2 miles. On the west flank of the Chickasha anticline, in Sec. 34 and 35, T. 4 N., R. 8 W., the interval varies considerably and averages 220–230 feet.

In some parts of this area some of the middle Rush Springs more nearly resembles Marlow than Rush Springs. I worked with this middle Rush Springs member, and it is on the basis of this work that I secured the intervals herein given. The evidence secured here, together with other evidence in the Anadarko basin, suggests to me that there is an unconformity at the base of the Cloud Chief, or what is considered Cloud Chief in that area.

RUSSOM (written discussion): Lehman has shown that the Rush Springs member of the Whitehorse formation has a minimum thickness of about 210 feet near the town of Rush Springs, which is considerably less than in many places. This would make the thickness of the Marlow and Rush Springs about 310–320 feet in this area, depending on individual measurement. From measurements made in the northeast part of T. 5 N., R. 11 W., and the northwest part of T. 5 N., R. 10 W., the writer found the minimum thickness of Marlow and Rush Springs to be 310 feet. In Sec. 15, T. 4 N., R. 10 W., near Fletcher, the maximum thickness of these two members was found to be 460 feet. These figures would vary somewhat according to individual measurements. Thus there is a difference in thickness of approximately 150 feet in a few miles. Other intervals in the same general area from the base of the Marlow to the base of the Cloud Chief are: 365, 400, 415, 435, and 450 feet. From these figures it seems that there is enough difference of interval from the base of the Marlow to the base of the Cloud Chief to warrant the sup-

position that an unconformity of some magnitude exists. The Cloud Chief bed in question is that found from Fort Cobb to Rush Springs.

Heterogeneous Character of Red-Beds

Gould commented on the heterogeneous character of the Red-Beds sediments and their lateral variations, and remarked that if Cragin had had modern transportation facilities, and had been able to view the exposures from southeastern New Mexico to Kansas, he would probably have formulated a quite different classification.

If you are ever in the vicinity of Carlsbad, New Mexico, do not fail to see the section exposed in Rocky Arroyo, about 30 miles northwest of Carlsbad. In approaching it, one follows the limestone section up the valley of Pecos River into Rocky Arroyo, which is ¾ mile in extent. At one end is typical Capitan limestone-dolomite, making a bluff 150–200 feet high. At the other end is as typical a Red-Beds section as you ever saw, except that on top is a dolomite ledge which holds up the bluff. When I saw that gradation in sediments, I thought anything could happen in Red-Beds stratigraphy.

Quartermaster Formation

Griley (written discussion): The exact relationship existing between the well known red, shaly part of the Quartermaster and the overlying 150 feet, more or less, of cross-bedded Elk City sandstone is difficult to determine. The presence of numerous slump faults in the area around the town of Cheyenne and the absence of good marker beds leaves the problem still unsolved. Various things observed in a study of localized exposures indicate conformity between the Doxey and Elk City members.

The abundance of large well rounded and frosted grains in the Elk City sandstone, the presence locally of a dolomitic zone at its base, the occurrence of cylindrical, vertically oriented, jointed masses said by Reed of the U. S. Geological Survey probably to be *Calamites*, the absence of teeth of amphibians, the absence of fossil wood, *et cetera*, indicate Permian age for the Elk City rather than Triassic.

Roth (written discussion): Mr. Griley has listed a number of points which to him are proof that the Custer group is Permian rather than Triassic. In considering these points Mr. Griley has overlooked an important fact. He states: "the absence of teeth of amphibians, the absence of fossil wood, *et cetera* . . . " In observing the sediments adjacent to the Mid-Continent it will be noted that fossil wood, amphibians, *et cetera*, have so far been reported only from the Keuper or upper Triassic. It is to this part of the Triassic that the Dockum group belongs. The characteristics of the Upper Triassic are not criteria for the Lower Triassic. Characteristics of the Blaine formation do not hold for other Permian formations.

The Muschelkalk or Middle Triassic has not as yet been observed east of Idaho.

The Bunter or Lower Triassic was a period of maximum Triassic deposition in North America. The character of the sediments comprising the following groups, for the most part Lower Triassic in age, have been studied in the field: the Chugwater of Wyoming below the Popo Agie beds; the Spearfish of South

Dakota; the Lykins of Colorado, and the Moenkopie of Arizona, New Mexico, Utah, and Colorado. In each case large well rounded and polished orange sand grains are abundant; also anhydrite, salt, and dolomite are present in connection with terra cotta shale.

GRILEY: I have been misquoted to some extent on my subdivision of the Quartermaster. The divisions were listed[16] in ascending order as: Bessie silt (named by Schweer and Buckstaff), Doxey shale, and Elk City sandstone. The original description of the Quartermaster by Gould includes references to these three parts of the formation.

Much discussion has occurred among field geologists about the lower limit of the Quartermaster. A line should be chosen which (1) conforms as nearly as possible to the original description of the formation, (2) follows, as nearly as determinable, a stratigraphic line, and (3) forms a boundary which is practicable for field use.

The writer once suggested the top of a massive sandstone which can be found in many places about 35 feet below the Day Creek-Cloud Chief. This line marks a slight change in sedimentation and the development of some local unconformity. At this horizon we have the Weatherford gypsum-dolomite, and its probable counterpart, the Saddle Horse lentil of the Texas Panhandle. There are various objections to the use of this horizon as a formational boundary.

GRILEY then showed a slide of the Elk City sandstone, which he described as cross-bedded, and containing, commonly, large round frosted grains in fine-grained matrix, also much mica on some bedding planes. He expressed doubt as to its relationship to the subjacent Doxey, but stated he has seen much evidence supporting the idea of conformity.

GREEN: If I misquoted Griley concerning the Quartermaster I did not speak my thoughts. I am quoting Griley for the definition of the Doxey shale and the Elk City sandstone. My idea in delimiting the base of the Quartermaster to the base of the Doxey shale is from Noel Evans' work in northwestern Oklahoma. I now agree with Evans that this is the logical place for the division between Cloud Chief and Quartermaster.

GRILEY showed a slide of the satin-spar zone in Bessie silt.

This member is composed largely of silty clay, gypsiferous in its lower part wherever it rests on Cloud Chief gypsum. The Bessie is present in southwestern Oklahoma and in Palo Duro Canyon, Texas Panhandle. The top of the Bessie is a line marking a certain depth of red color and a certain degree of even bedding, and its position is dependent on the content of disseminated gypsum in the clay. The position is variable and transgresses bedding. Such a line is sufficient for a member boundary but should not be taken as the base of the formation. The top of the bedded dolomite and gypsum of the Day Creek-Cloud Chief should be the base of the Quartermaster.

[16] H. L. Griley, "Subdivision of Quartermaster Formation of Oklahoma, Its Relationship to Known Triassic of Texas Panhandle," abstract printed in program of the eighteenth annual meeting of the Association, Houston, Texas, 1933.

Another slide was shown of Gould's section from *U. S. Geological Survey Water-Supply Paper 148* (1905), for an area 5 miles northwest of Weatherford, picturing

massive Whitehorse sandstone capped by 2 feet of dolomite, and succeeded upward by 30 feet of red clay shale, then massive gypsum of the Cloud Chief. Except for the intergrading of gypsum and dolomite this section can be traced over a wide area.

GRILEY showed a slide giving his summary of the Red-Beds problem in 1932.

I believe dolomite and gypsum of the Day Creek, Alibates, and Cloud Chief are all equivalent in spite of facies change. Gypsum was formed in the deeper parts of the sedimentary basins, and dolomite in shallow-water areas. A small amount of local unconformity is present at the top of the massive sandstone of the Whitehorse, with the development of the "purple slate" in saucer-like depressions in its upper surface. A much greater amount of unconformity resulted from local non-deposition or erosion of Cloud Chief-Day Creek gypsum and dolomite. The Doxey shale is found in contact with the Whitehorse sandstone in parts of the Clinton-Weatherford area, as described by Evans.[17]

GREEN: Is the top of the Cloud Chief at the base of the Doxey?

GRILEY: The whole question seems to be: what is the top of the Cloud Chief?

GREEN: Don't you think the color change and gypsiferous shale the most logical position for a break?

GRILEY: No. I have given this question considerable study.

RUSSOM: Green and Evans, are you agreed on Evans' subdivision, that the base of the Doxey shale should be the base of the Quartermaster?

EVANS: Yes. GREEN: Yes.

RUSSOM asked about the unconformity above the Rush Springs sandstone. Green believes it is below the Cloud Chief, and Evans that it is above the Cloud Chief.

BROWN: Another question I have for Mr. Green is that of unconformity at the top of the Marlow.

GREEN: That occurs in only one locality north of Bridgeport, and has no extent or importance.

ROTH: From the discussion here tonight it would seem that the unconformity at the base of the Custer group or base of the Marlow is the only one on which there is any unanimity of opinion. Such unconformities as may occur above the base of the Custer appear to be of a local nature and are

[17] Noel Evans, "Stratigraphy of the Weatherford Area, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12 (1928), p. 705.

regionally so obscure that no agreement as to their lateral extent has been expressed here tonight.

GRILEY: Close to the point where the Duncan dies out near Kingfisher is a perfect development of local unconformity. I had never mentioned it because I thought it had no significance. At this point about 6 miles southwest of Kingfisher the sandstone is approximately middle Duncan (restricted), the lower part being absent by gradual gradation northward to shale. A depression at least 6 feet deep and about 25 feet wide formed in shale containing very definite white layers or bands which were cut out at the point of erosion. Duncan sandstone fills this depression but on either side there is no evidence of unconformity.

GOULD: I wonder if any one geologist has studied the Red-Beds at their most northerly exposures on the Great Plains, at Arlington, Kansas, also on the Pecos River, in New Mexico, and at intervening points. It is a regional problem, and can be solved only by regional studies.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 12 (DECEMBER, 1937), PP. 1573-1574

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 12 (DECEMBER, 1937), PP. 1575-1591, 4 FIGS.

GEOLOGICAL NOTES

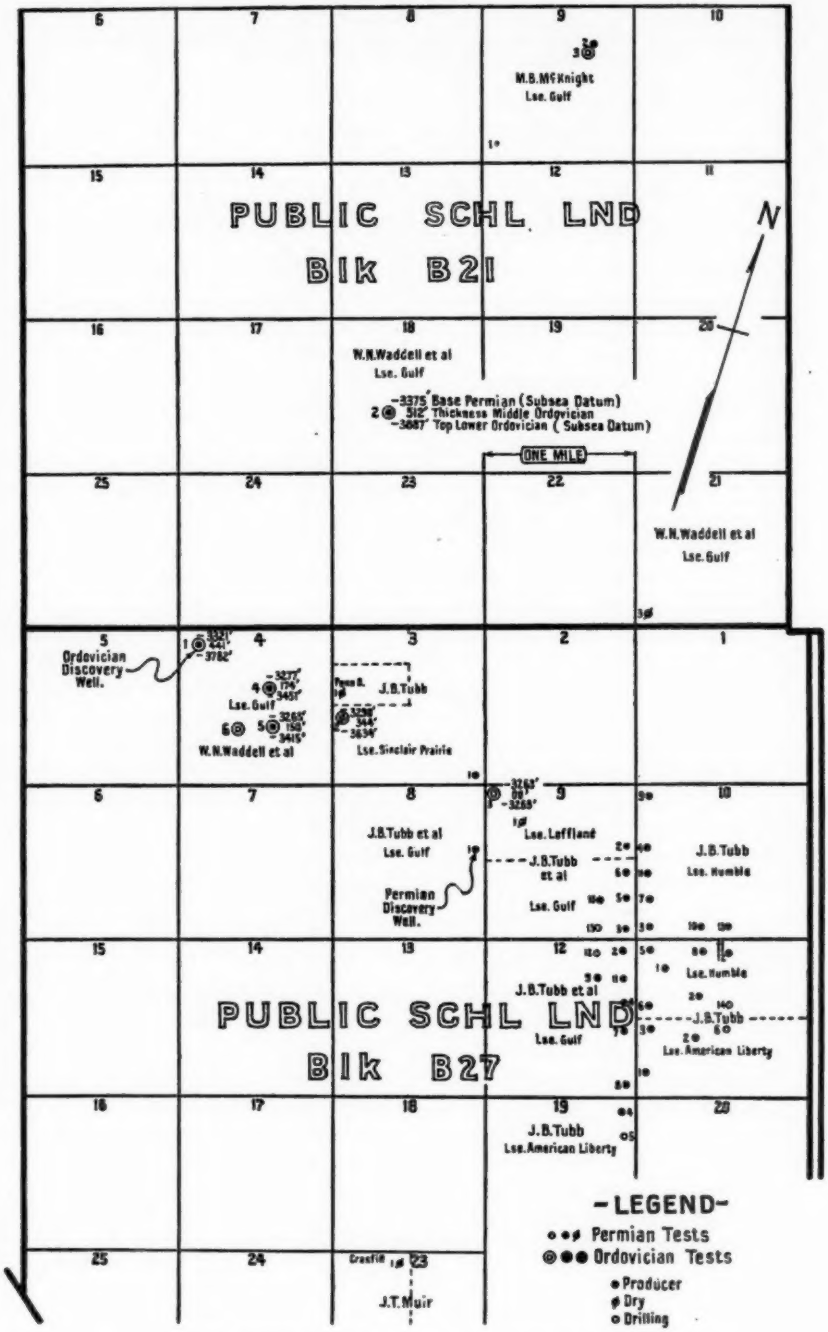
ORDOVICIAN DEVELOPMENT, SAND HILLS STRUCTURE, CRANE COUNTY, TEXAS

The Sand Hills structure is located in west-central Crane County, Texas, and occupies a central position on the West Texas structural platform. Subsurface information obtained from tests seeking production in the Permian dolomite had revealed the presence of a large structure in this area. Subsequent core drilling was done to obtain more detailed information for the purpose of locating an Ordovician test.

The Gulf Oil Corporation's W. N. Waddell *et al.* No. 1, located 694 feet south and 560 feet east of the northwest corner of Section 4, Block B-27, Public School Lands Survey, was completed, February 6, 1936, after having plugged back to 6,317 feet from a total depth of 6,450 feet. The test pumped 122½ barrels initial from a depth of 5,980–6,290 feet.

This test penetrated a series of Permian Red-Beds, salt, and anhydrite to a depth of approximately 2,400 feet. From this depth to 5,875 feet the section consisted of Permian limestone and dolomite, at which depth the first Ordovician sediments were encountered. The section extending from 5,875 to 6,316 feet consists of a series of dense brown limestone, green shale and sandstone. Fossils found in this section, such as *Aparchites perforata*, *Schmidtella* sp., and *Eridoconcha* sp., are diagnostic and indicate these sediments to be of Middle Ordovician or Simpson age. The best devoloped sandstone occurred between 5,980 and 6,040 feet, and this zone probably yields most of the production developed in this test. The top of the Lower Ordovician (Ellenburger) dolomite was encountered at a depth of 6,316 feet and penetrated to 6,450 feet. The first porosity was noted in the cores at a depth of 6,344 feet, but was best developed from 6,386 to 6,450 feet. A drill-stem test, with the packer set at 6,360 feet, showed sulphur water to be present in this section.

At present six tests have been drilled into the Lower Ordovician dolomite: four by the Gulf Oil Corporation on their Waddell *et al.* tract; one by the Sinclair-Prairie (Unit) on the Tubb lease; and one by Loffland Brothers on the Tubb tract. Reference to Figure 1 showing development in this area indicates the location of these tests and also the location of wells which have been completed in the Permian dolomite section. Production from the Permian is obtained at ap-



Development of Sand Hills Structure, Crane County, Texas

FIG. 1

proximately the 4,300-foot level. However, this production has been confined to the eastern part of the structure because porosity was not present in tests drilled immediately to the west. A small amount of production has been developed on the McKnight lease at approximately the 3,500-foot level.

The Gulf's No. 2 test, drilled 2 miles northeast of No. 1, encountered a section similar to the discovery well except for an additional 71 feet of Middle Ordovician beds beneath the contact of the Permian dolomite. Being 125 feet lower structurally on the Lower Ordovician dolomite than the original well, this test also encountered sulphur water, after having penetrated 202 feet of the dolomite. The test was completed as a 25-barrel pumper from the Middle Ordovician sand found from 6,152 to 6,230 feet. The lower part of this sand contained water and the test was plugged back to 6,186 feet.

Their No. 4 and No. 5 wells, located approximately ½ mile southeast of the discovery test, were completed with approximately the same penetration (15 feet) in the Lower Ordovician dolomite, with initial productions of 1,800 barrels and 8,000 barrels, respectively. Production is coming from a porous dolomitic horizon in the lower Simpson and from a porous dolomite in the upper few feet of the Lower Ordovician. The Simpson sand present in No. 1 and No. 2 wells was absent because of pre-Permian erosion in both the No. 4 and No. 5 tests, which had 174 feet and 150 feet, respectively, of lower Simpson beds. Neither of the first drilled wells found porosity near the Simpson-Lower Ordovician dolomite contact and neither the No. 4 or No. 5 tests penetrated the lowermost porous zones found in the first two tests. The No. 4 and No. 5 tests are respectively 311 feet and 347 feet higher structurally than the discovery well on the Lower Ordovician horizon.

The Sinclair-Prairie's (Unit) Tubb No. 2 test, located ½ mile east of Waddell *et al.* No. 4 has been abandoned in Ordovician sediments after drilling to a total depth of 6,391 feet. This test encountered 344 feet of Middle Ordovician beds and penetrated the Lower Ordovician dolomite at a depth of 6,186 feet, or 183 feet lower than the Gulf's Waddell *et al.* No. 4. Cores taken from this test in the lower part of the Simpson section showed the dip of the formation to be increasing decidedly with depth, until a maximum of more than 50° was observed. The presence of such abnormally high dips probably indicates the presence of a fault or fault zone. This test penetrated 205 feet of Lower Ordovician dolomite, and when tested, sulphur water could not be lowered below 3,800 feet.

The Loffland Brothers Tubb *et al.* No. 3 test, located one mile

southeast of the Sinclair test, found beds of Permian age resting on the Lower Ordovician dolomite with no Middle Ordovician sediments present. Though it is not definitely known how much of the Lower Ordovician may have been removed by pre-Permian erosion, the test, based on this contact, is at least 152 feet higher structurally than Waddell *et al.* No. 5, which had an initial production of more than 8,000 barrels. Porosity was encountered immediately below the contact in the Loffland test and when tested the well flowed a small stream of sulphur water with no oil or gas. The test is at this time drilling ahead at 6,693 feet, having penetrated 890 feet of Ordovician dolomite with no showings of oil or gas reported. At the present stage of development several hypotheses may be advanced to explain the apparent failure of the Loffland test, but any definite explanation must await future development in the area.

At the present time the Gulf Oil Corporation is drilling its McKnight No. 3 and Waddell *et al.* No. 6, in order to explore further the possibilities of Ordovician production in this area. The McKnight test is located 2½ miles northeast of Waddell *et al.* No. 2, while the No. 6 test is a west offset to the No. 5 producer.

The porosity encountered in the Waddell *et al.* No. 4 and No. 5 tests has consisted of a cavernous and brecciated dolomite and the large initial yields in these wells indicate excellent permeability. Calculations on the No. 5 test show the bottom-hole pressure to be 2,750 pounds. The gravity of the oil in the dolomite producers is 45° Bé., while that in the two sand producers is 34.7°.

Information obtained from additional Ordovician development in the area will in all probability reveal the presence of several very complexly folded and faulted subsidiary structural features superimposed upon the main uplift.

October 6, 1937

The Loffland Brothers J. B. Tubb *et al.* No. 3 test has now been abandoned at a total depth of 7,158 feet, after encountering pre-Cambrian granite or gneiss at 7,115 feet. The principal minerals present in the granitic formation consist of pink and gray feldspar, quartz, and biotite mica.

The Lower Ordovician dolomite was encountered at 5,803 feet and dolomite was drilled continuously to 7,115 feet, except for slightly sandy beds from 7,045 to 7,115 feet, the total thickness being 1,312 feet. The lower part of this section may be Upper Cambrian, although no definite Ordovician-Cambrian contact has been determined at this

time. This section is also correlated as a partial equivalent of the Ellenburger limestone of central Texas.

C. D. CORDRY

GULF OIL CORPORATION
FORT WORTH, TEXAS
October 21, 1937

"BLACK SEA" CONDITIONS IN THE ARABIAN SEA

I am stimulated by the excellent article on "Barred Basins and Source Rocks of Oil" by my friend W. G. Woolnough in the September *Bulletin* of the Association to bring to the notice of oil geologists an important recent discovery which appears to have escaped general attention. I refer to the discovery in the open ocean of extensive patches of "Black Sea" conditions off the Arabian coast by the John Murray Expedition to the Arabian Sea in 1933. The complete data of this expedition have not yet been published and it is therefore uncertain whether or not these euxinic patches are controlled by low-lying bars; the alternative, which seems more likely, is that the area concerned is a still backwater between two or more systems of marine currents and that a complete lack of water circulation is responsible for the stagnant conditions.

The following paragraphs are extracted from a preliminary statement on these results published by R. B. Seymour Sewell in *Nature*, January 20, 1934, pp. 86–89.

Where not composed of rock, the bottom consists of a brown or green mud, and towards the eastern end in the neighborhood of Ras al Hadd [the most easterly extremity of Arabia] this green mud smells very strongly of sulphuretted hydrogen. Six observations showed that this is present between the depths of 95 metres and 1,253 metres, though most strongly marked at 421–457 metres, the occluded water from a bottom-sample at 421 metres containing as much as 29.39 milligrams of sulphuretted hydrogen per litre. This occurrence of sulphuretted hydrogen in the bottom deposit affords a parallel to the conditions found in the Black Sea and in some of the enclosed fjords, but its presence along an open sea-coast was scarcely to be expected and its cause must at present remain unsolved. A very similar mud bottom composed of green mud, or in the deepest depths of a grey clay, but not impregnated with sulphuretted hydrogen, is found throughout the whole of the Gulf of Oman and along the coast of Makran and Baluchistan below a depth of about 250 metres.

BIOLOGICAL OBSERVATIONS

On the biological side, two areas have proved to be extremely interesting—not because of the richness of their fauna, but, on the contrary, because of its paucity or even complete absence. The first is the deep part of the Red Sea. During our cruise down this region in September, we carried out several

ARABIAN COAST

Station Number	*Depth in Metres*	*Character of Bottom*	*Results*
53	13	Rock: Lithothamnioneae	A good and varied catch
80	16–22	Sand and shells	A good catch
45	40	Lithothamnioneae, etc.	A good and very interesting catch
43	83	? No sample obtained	A small but interesting catch
79	102	Green mud (H_2S)	Very little animal life
48	201	Rock	A very small catch. Net torn
77	350	Green mud (H_2S)	A single crab; *Paralia alcocki*
56	457	Green mud (H_2S)	No living organisms; dead shells of *Rostellaria delicatula* and *Encephaloides armstrongi*
57	428–750	Green mud (H_2S)	Very little life; one dead shell of *Rostellaria delicatula* and a few moribund *Encephaloides armstrongi*
55	802	Stratified green mud	No sign of living organisms
54	952	Green mud and soft rock	A good catch; thousands of Ophiuroids
58	1,253	Green mud (H_2S)	A single crab: *Paralomis* sp.
50	1,536–1,737	Brown mud	Catch very small
59	1,977	Soft green mud	Catch very small

GULF OF OMAN

Station Number	*Depth in Metres*	*Character of Bottom*	*Results*
72	75	Grey clay and shells	A good and varied catch
71	106	Grey-green mud and sand	A moderate catch
70	109	Soft green mud	Moderately good catch; 213 living examples of *Rostellaria delicatula* and several *Pirula* sp.
75	201	Soft green mud	A good catch
67	269	Soft green mud	No living organisms; dead shells of *Rostellaria delicatula* and a few Serpulid tubes
64	448	Grey clay	No signs of living organisms
66	610	Brownish-green mud	Several dead shells of *Rostellaria delicatula* and 3 living examples; a few Serpulids
65	912	Green mud	No living organisms
68	1,491–1,518	Soft green mud	No living organisms
81	3,350	Grey mud	Two starfish

trawls and dredges in depths ranging from 55 metres to 1,167 metres, and in four hauls in depths below 260 metres we were unable to detect any sign of living organisms on the bottom, which as already mentioned, consists of a calcareous rock that appears to be in process of formation *in situ*.

In view of the enclosed character of the basin, the depth of the entrance channel at Great Hanish Island just to the north of the Straits of Bab el Mandeb being only some 160 metres, the water of the Red Sea below this depth, as is well known, has a very high salinity (40 per mille and above) and a high temperature (22°–23°C.), though the oxygen content of the bottom water is higher than we expected to find and ranges from 1.32 to 1.65 c.c. per litre at depths between 800 metres and 1,500 metres in the northern part, sinking to less than 1.0 on the bottom in the southern area; but such conditions are of themselves scarcely sufficient to account for the complete absence of life.

The discovery of the second area, in which all life is either completely absent or is extraordinarily scanty, came as a complete surprise. I have already referred to the region of the Arabian coast near Ras al Hadd, where we discovered a bottom deposit of soft green mud that smelt strongly of sulphuretted hydrogen; such an area we would expect to find largely, if not entirely, devoid of animal life but this azoic area appears to extend far beyond the limits of the region where sulphuretted hydrogen is to be found and can be traced throughout the whole extent of the Gulf of Oman. In this latter area the bottom consists of either a soft green mud or a grey clay, and between the depths of approximately 300 metres and 1,750 metres there is an almost complete absence of animal life, and even at so great a depth as 3,351 metres an hour's trawl only resulted in the capture of two starfish.

In the accompanying tables I have given the various stations and their depths in the Gulf of Oman and off the Arabian coast, and it seems clear that this azoic area not only lies at a deeper general level in the Gulf of Oman than on the Arabian coast, but also that there is a difference of level on the two sides of the Gulf of Oman. The upper limit of the azoic area on the Arabian coast near Ras al Hadd lies somewhere between 83 metres and 102 metres and the lower limit between 1,253 metres and 1,536 metres. The depth of the lower limit, however, probably increases as we pass towards the northeast, where we found prolific life at a depth of 952 metres, the trawl bringing up a number of fish and crustacea and thousands of Ophiuroids; in 1906 the R.I.M.S. Investigator, when trawling in the near vicinity, also secured a good catch, though the net was badly torn (*vide* Lloyd, 1907, p. 2). There can thus be little doubt that this area is a fertile one; but a little to the east at a depth of 1,253 metres we were within the zone of sulphuretted hydrogen and the catch after an hour's haul consisted of a single crab, *Paralomis* sp.

In the Gulf of Oman, the upper limit of the dead area appears to lie at a slightly different level on the two sides. On the southern side in the vicinity of Muscat the great bulk of the fauna disappears between 210 and 269 metres, though a few live animals were obtained at a depth of 610 metres; off the coast of Persian Makran no life was detected at a depth of 448 metres and it is somewhat significant that these levels correspond very fairly closely with the upper level of the deep inflowing mass of water that is running up the Gulf under the out-flowing Persian Gulf water. That this water is not *per se* responsible for the absence of life is clearly shown by the results of several horizontal hauls at depths down to as much as 1,500–2,000 metres, for at all depths numerous red deep-sea prawns and small fish, such as *Bregmaceros* sp. and Scopelids, were obtained. It would appear, therefore, that the sterility of the area must be attributed either to some harmful character of the bottom

deposit or else to some seasonal change in the general conditions of the deep water.

The surface waters and the inshore areas in both regions, in marked contradistinction, appear to be particularly fertile. Along the Arabian coast we have carried out several successful trawls, special attention being paid to areas where the charts indicate the presence of coral; in every case we have found that true reef-forming corals are absent, though we have dredged a number of specimens of Lophohelia, Caryophyllia and Flabellum, some still living, though many of them dead. The chief ingredient of the reef appears to be Lithothamnioneae.

G. M. LEES

ANGLO-IRANIAN OIL COMPANY
LONDON, ENGLAND
October 22, 1937

ORISKANY EXPLORATIONS IN PENNSYLVANIA AND NEW YORK

METAMORPHIC CRITERIA

The carbon-ratio theory, having been proved generally reliable in Pennsylvania, was used as a reliable guide in 1931. The northwestern part of Bradford County was then considered desirable gas or possible oil territory. From a mineralogic study of the exposed Chemung shale, and more especially at the faults, it was considered that metamorphism had gone too far. This high degree of metamorphism was confirmed by finding fossil plant remains (probably *Archaeopteris*). Carefully collected coaly matter from the fronds yielded the following analysis.

	Per Cent
Volatile matter	20.1
Fixed carbon	79.9

The sample was from the vicinity of Wysox and definitely made the Towanda anticline seem unfavorable.

A new criterion for the location of possible oil in the Oriskany was developed by the study of natural gases found in the Oriskany structures. A tabulation of Oriskany gas analyses is here given.

	Sabinsville Anticline Tioga County, Pa.	*Fir Tree Anticline Wayne County, N.Y.*	*Allen Anticline, Allegany County, N.Y.*
	Per Cent	*Per Cent*	*Per Cent*
Methane	99.5	97.2	80.9–83.7
Ethane	0.0	1.5	8.1–10.4
Propane	—	—	2.9– 2.8
Butane	—	—	1.1

These analyses show that farther from the source of metamorphism, that is, from the "Mountain Front" northwesterly, there are more ethane and heavy hydrocarbon gases. Conversely, nearer the mountains, pyrolysis of hydrocarbon gas has taken place until only the chemically inert methane remains.

This corresponds with theory, because it has been shown[1] that methane is a relatively inert gas as far as chemical activity is concerned. This inertness toward chemical change is to be correlated with

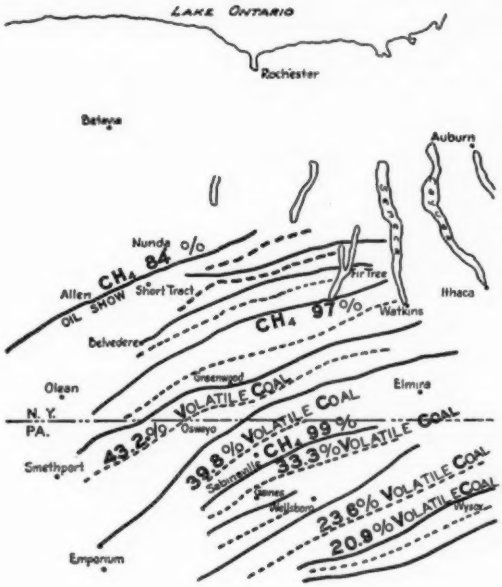


FIG. 1

evidence from ionization-potential experiments which indicate that the outer "shell" of the methane molecule consists of eight electrons similar to the arrangement in rare gases like argon and krypton. Oxygen reacts readily with most organic compounds except methane, where only slow reaction has been observed.

If the methane content of gases from the same horizon are put on a map "isomethanes" like isovols of coal are observed.

In order to get a picture of the use of methane and its relation to metamorphism, plot a map northwest from Williamsport, Pennsylvania, toward Niagara Falls, New York (Fig. 1).

Towanda	20.9 per cent volatile		79.15 fixed carbon
Blossburg	23.6		76.4
Wellsboro	32.4		67.4
Pine Creek	33.3		66.7
Tioga field	GAS	99 per cent	METHANE

[1] H. H. Storch, "Physical Chemical Properties of Methane," *U. S. Bur. Mines Rept. Investig. 6549* (1932).

Cowanesque	39.8		60.4
Hebson gas field said to have less methane than Tioga			
Oswayo	43.2		56.8
FIR TREE (Wayne field)		97 per cent	METHANE

Then count about three or four anticlines and METHANE 84 per cent. The following surface criteria may be used.

1. Shales east of Towanda anticline, almost slates with wrinkled or slip cleavage
2. Shales up to Sabinsville anticline with smooth cleavage
3. Beyond Sabinsville anticline shales with rough cleavage and with unoriented sericite (mica) flakes causing imperfect cleaving
4. Beyond Fir Tree anticline shales showing some clay and lacking slaty cleavage but showing some regularity of joint-like, closely spaced fractures or possessing a slate-pencil-like fracture. No use to look for oil except in places where "pencil cave" of drillers can be found
5. Unctuous clay shale
6. Plastic clay shale

Crude oil was found in the Oriskany horizon at the Allen anticline where the methane had dropped to about 80 per cent and shales had a slate-pencil-like fracture.

This oil sample from Fannie Woodruff well No. 1, Allen anticline, Allegany County, New York, 6-28-33, gave

Specific gravity	0.7809	A.P.I. gravity	44.6°
Per cent sulphur	0.18	Color O.D.	12.5

Temperature (Vapor) °C	*Per Cent Cut*	*Sum Per Cent*	*Gravity °A.P.I.*		
75	1.5	1.5	75.9		
100	4.0	5.5	61.2		
125	2.9	8.4	61.7		
150	3.2	11.6	59.1		
175	5.1	16.7	56.3		
200	7.2	23.9	53.9	Vis. at 60° F.	270
225	8.3	32.2	51.4		340
250	8.2	40.4	48.5		470
Vacuum Distillation at 10 MM. Pressure					
133	5.6	46.0	46.5		
158	6.6	52.6	44.5		
183	9.9	62.5	43.0	Vis. at 100° F.	40
208	10.9	73.4	40.8		44
233	5.8	79.2	38.2		59
258	4.3	83.5	36.1		80
283	4.8	88.3	34.3		132
Bottoms	10.4	98.7	27.6	Vis. at 210° F.	106
Loss	1.3	100.0			

The viscosity/gravity constant is 0.806.

These results are not set up in exact comparison with *U. S. Bureau of Mines R.I. 3279;* however, they clearly show the Oriskany crude to be paraffine-base oil (wax-bearing) similar to the commerical grade known as "Milltown crude" as collected at Haffey Post Office near New Texas, Allegheny County, Pennsylvania. The viscosity /gravity constant of Oriskany is 0.806 and "Milltown" 0.792.

INFLUENCE OF FAULTS AS POSSIBLE TRAPS

Through the courtesy of Thurman Myers of Wellsboro, Pennsylvania, several samples of Oriskany sandstone blown from wells were tested for porosity.

		Percentage of Porosity
Palmer Well	7.4, 7.4, 7.7,	8.5
Farr No. 1	4.0, 4.1, 4.9,	5.0
Close No. 1		10.4
Wilston & Kuhl No. 1 (giving 13½ million cu. ft. gas)		10.6
Leslie No. 1 (giving 40 million cu. ft. gas)		9.2

The last two determinations show that porosity alone does not control volumetric capacity of wells, since the larger producer had the lesser porosity.

Specimens of Oriskany sands from wells drilled farther in the synclines have smaller grains than those from wells on the anticlines. As sediments deposited on submarine topographic "highs"[2] should compact less than those that accumulated in "lows" and as an irregular north-south corrugated surface before the deposition of the Oriskany had been inherited from Taconic folding, such sorting of sand grains was to be expected. Therefore, the crossings of lines of Taconic "highs" by Appalachian anticlines are most likely to be porous.

Some of the Oriskany sands were found re-cemented. An example was Russell No. 2, Tioga County, Pennsylvania. This well found the top of the Oriskany at 4,102 feet. It encountered "hard rock" at 4,108 feet. This was thought to be "Helderberg" and it was feared that drilling into it would result in a flow of salt water. However, the "hard rock" looked so much like the Oriskany iron ores of Virginia, that a qualitative analysis was made. After heating in *aqua regia* for 10 hours, the specimen disintegrated. The cement was greater in iron than alumina; alumina greater than magnesia; there were traces of soda and potash but no lime. The residue after acid treatment was quartz typical of the Oriskany. Drilling through the locally hardened iron ore resulted in increased production, following shooting.

The author, working independently, confirmed Fettke's observation of secondary growth of quartz crystals in vugs in Oriskany sandstone from the Sabinsville anticline wells. This fact, together with the demonstration of porosity on Wilston and Kuhl and on Leslie sandstone samples, as well as subsequent drilling results, demonstrated that faulting was an important factor in forming Oriskany reservoirs.

Suggestions of pre-Devonian structure may be had from a study

[2] Parker D. Trask, "Compaction of Sediments," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 3 (March, 1931), p. 271.

of published salt-well logs. Some surface manifestations of faulting in the Chemung may be seen at Little Meadows in the extreme northwest corner of Susquehanna County, Pennsylvania. Along Apalachin Creek northward into Tioga County, New York (not Pennsylvania) for about 3 miles, faulting may again be seen. About a mile farther on Deerlick Creek, overthrusting may be observed. At Ford's Glen, on Big Choconut Creek, there is an expression of overthrust faulting. The well at Vestal, New York, was dry but there is some question if this well really found Oriskany or stopped in Esopus.

The "Large Fault in Western New York" mentioned by G. H. Chadwick[3] could not be detected in the field. There is some evidence of faulting and recrystallization of halite in the Retsof mine but no substantial vertical throw. Mining engineer LaVergne has no record of faults on his underground map.

There is a shortening of interval between Caledonia and LeRoy, with a possible upthrow toward the south. The log of the Nunda well compared with the log of the Dansville well indicates Dansville to be 200 feet lower than Nunda. The suggestion that the block from Dansville to LeRoy is a horst is interesting but not proved. F. J. H. Merrill (Fig. 2)[4] studied the Oatka Valley approximately 20 miles west of this section and found a considerable anticline.

There is some rather superficial surface evidence of faulting near the old Short Tract pool. Hartnagel gives evidence to support the idea that the Short Tract oil field was due to a fault.[5]

> The oil in the Short Tract and Grove oil pools was in crevices in the brown shale. There was no sign of any true sand in these wells near the horizon at which the oil occurred. . . . The total production from the Short Tract pool was somewhat over 3,000 barrels of light-colored amber oil.

S. H. Cathcart and the writer found vertical dips in the valley of Wigwam Creek, about 2 miles east of Belfast, near Allen Township line, Allegany County, New York. The trend of this was N. 20° E. (Fig. 3).

Plotted logs supplied by drillers of wells on a section N. 17° W. from Belvidere to Hume, New York, indicate a fault between No. 4 Sleight and No. 6 Vincent wells on the Allen anticline. The Woodruff well gave oil, of which an analysis has already been given. Adjoining wells gave gas, of which the analysis, calculated on volume per cent, airfree base, is as follows.

[3] G. H. Chadwick, "Large Fault in Western New York," *Bull. Geol. Soc. America* (1920), p. 117.

[4] F. J. H. Merrill, "Salt and Gypsum Industries of New York," *New York State Museum Bull. 11*, Vol. 3 (April, 1893), plates after p. 32.

[5] C. A. Hartnagel, letter to S. H. Hamilton, dated Albany, New York, September 16, 1931.

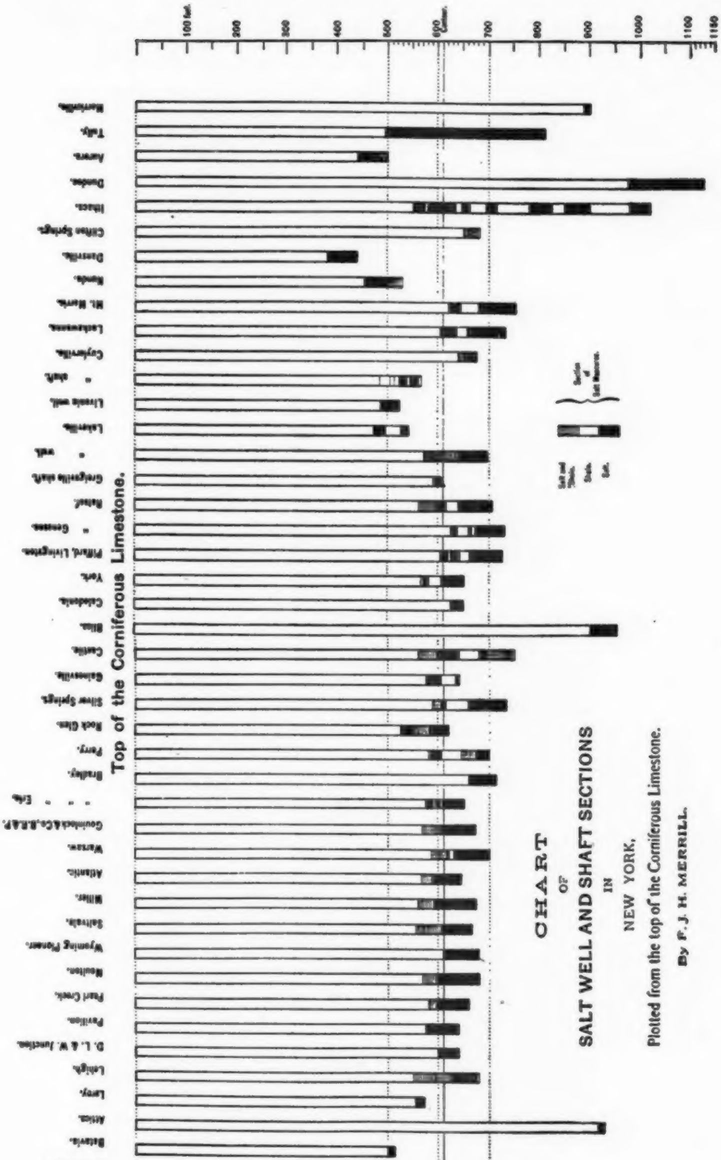

Top of the Corniferous Limestone.
CHART
OF
SALT WELL AND SHAFT SECTIONS
IN
NEW YORK,
Plotted from the top of the Corniferous Limestone.
By F. J. H. MERRILL.

FIG. 2

	Smith Well Allen Township Allegany County, New York	*Kerr and Kaufman Well Allen Township Allegany County, New York*
	Per Cent	*Per Cent*
Nitrogen	6.5	1.0+ or −0.5
Hydrogen	—	0.3+ or −0.1
Carbon monoxide	—	0
Methane	80.9	83.7+ or −0.5
Ethylene	—	0
Ethane	8.1	10.4+ or −0.3
Propylene	—	0
Propane	2.9	2.8+ or −0.3
Butylenes	—	0
Butane	1.1	1.1+ or −0.3
Pentane and heavier	0.6	0.7
	Determined specific gravity	0.671
	(Air=1) Calculated specific gravity	0.665

FIG. 3.—Exposure showing vertical dips in valley of Wigwam Creek, about 2 miles east of Belfast, Allegany County, New York.

The Oriskany sand from the Allen wells was very fine and in some wells so tight as to be spoken of as "cemented" by the drillers.

In the writer's opinion a study of the Allen field indicates, although both "isomethane" and faulting criteria were present to indicate a probable pool, that the conditions were not favorable to commercial production because the Oriskany sand had not been sorted on a Taconic corrugated sea bottom.

SUGGESTIONS ABOUT SOURCE OF HYDROCARBONS FOUND IN ORISKANY

The Helderberg limestone is exposed by the Selinsgrove anticline at Dalmatia Quarry, Northumberland County, Pennsylvania. This is dark, almost black limestone but burns to white lime. Petrographic examination of thin sections shows small areas of anthracite-like carbon. Solution in acid shows that this carbonaceous material is insoluble in ordinary hydrocarbon solvents. As was to be expected, any petroleum hydrocarbons the rock may have contained have been changed or lost owing to the proximity of the Mountain Front. The exposed Oriskany sandstone from this vicinity showed no trace of carbon or hydrocarbons.

In the New York State Museum at Albany is a contact specimen of a thin bed of Oriskany sandstone and Onondaga limestone from Erie County, New York. At the Williamsville Quarry, Erie County, New York, there is only a siliceous phase of the Onondaga to suggest an Oriskany interval between the Onondaga and the underlying formation.

In the Williamsville Quarry are found fossil corals (*Favosites, et cetera*) some of which are saturated with hydrocarbons. Some of these coralline masses exude a pleasant smell of machine oil when struck with a hammer. Others exude considerable heavy brown oil which covers an area of 100 square feet of the rock surface. A third phase is a shiny black material filling the coral cells. This looks like gilsonite but is not an asphalt. It is a wax with small carbon particles through it. This paraffinic rock consists of corallites filled with black, brittle paraffinic material. This paraffinic material was only 50 per cent soluble in chloroform and carbon disulphide.

The Onondaga limestone, on analysis, indicated more than 99 per cent soluble in hydrochloric acid with only traces of magnesium and barium. Some of the *Favosites* corals are not oily in any way, but are snow-white and studded with brilliant little quartz crystals. This siliceous phase of the coralline limestone is about 50 per cent soluble in hydrochloric acid. Of the insoluble residue about half was shale and half quartz.

Oil in Onondaga (*Favosites*) coral cells was extracted by boiling chloroform followed by boiling benzene. This extracted oil was found to have lost all volatile products by weathering. Seventy-five per cent of the oil was distilled overhead between 350° and 700°F. (177°C–371°C). This distillate had a beautiful yellow-green bloom characteristic of paraffine-base oils. It had a low sulphur content of 0.218 per cent. Considerable paraffine wax content was indicated by the pour point of 60°F. and the separation of crystalline wax. A small residue of coke was left in the distillation flask. The rock from which this oil was extracted was completely soluble in *HCl*.

This oil extracted from the coral limestone and the four samples of oil produced from the Oriskany horizon are very similar or identical, as the following comparisons show.

Distillation between 350° and 700° gave	*Per Cent*
Allen Township, Allegany County, New York	72.8
Kanawha County, West Virginia	72.5
North Salem, Ohio	79.1
Williamsville, Erie County, New York	75

Sulphur content, which is an excellent comparison for crudes was as follows.

	Per Cent Sulphur
Allen Township, Allegany County, New York	0.19
Raven Rock, Washington County, Ohio	0.19
Big Chimney, Kanawha, West Virginia	0.19
North Salem, Guernsey County, Ohio	0.15
Williamsville, Erie County, New York, weathered residue	0.218

The color of all the crude oils that have been produced from the Oriskany has ranged from green to amber with a yellow-green bloom. The oil extracted from the rock quarried at Williamsville has the same appearance. For purposes of comparison the following tabulation of crude oils from the Oriskany horizon is offered.

COMPARISON OF ORISKANY CRUDE OILS

	North Salem, Guernsey County, Ohio	*Big Chimney, Kanawha County, West Virginia*	*Raven Rock, Washington County, Ohio*	*Allen Pool, Allegany County, New York*
Gravity °A.P.I.	44.0	42.1	42.4	46.4
Color O.D.	12.4	12	13	10
Appearance	Red-green	Amber	Amber	Amber
Sulphur percentage	0.15	0.19	0.19	0.19
Cut gravities	°*A.P.I.*	°*A.P.I.*	°*A.P.I.*	°*A.P.I.*
175°C. 238°F.	52.9	54.5	54.6	56.3
200°C. 328°F.	50.5	32.0	52.3	53.9
225°C. 373°F.	47.8	49.9	49.6	51.4
250°C. 418°F.	44.9	46.8	47.1	48.5

Vacuum distillation at 10 MM. pressure				
133 °C. 207.4°F.	41.5	43.0	44.0	46.5
158 °C. 252.4°F.	41.1	42.6	42.0	44.5
183 °C. 297.4°F.	39.5	41.0	40.2	43.0
208 °C. 342.4°F.	37.6	39.0	38.7	40.8
233 °C. 387.4°F.	36.1	37.7	36.9	38.2
258 °C. 432.4°F.	34.4	35.9	—	36.1
283 °C. 541.4°F.	32.7	34.6	—	34.3
Bottoms	27.1	30.2	27.5	27.6

These analyses bring out clearly that, wherever found, the Oriskany crude has very constant characteristics of low sulphur, paraffine-base (wax-bearing) oil.

Some of the Oriskany gas wells produce a so-called "distillate" or "casinghead." The Allen pool, New York, and some of the West Virginia wells, but more especially the Jenkins well, Madison Township, Columbiana County, Ohio, gave this material. Two samples from Jenkins well were collected. One was the so-called "distillate" or crude and the other the "casinghead" from the drips.

	"Crude"	*"Casinghead"*
Gravity	44.1°A.P.I.	64.4°A.P.I.
S.T. Vis./60°F.	355	—
Color	½ A.S.T.M.	−16 Saybolt
Sulphur	0.08	0.02
Distillation at atmospheric pressure		
Initial boiling point	*°F.*	*°F.*
Per Cent	344	122
1	361	136
3	368	153
5	374	164
10	381	180
20	392	200
30	398	216
40	405	231
50	413	247
60	421	265
70	431	287
80	445	316
90	464	361
95	484	405
End point	519	442

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Philadelphia, Pennsylvania
October, 1937

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 12 (DECEMBER, 1937), PP. 1592-1594

DISCUSSION

UPPER CRETACEOUS OF ROCKY MOUNTAIN AREA[1]

Mr. Bartram's strong plea for the revision of the stratigraphic nomenclature of the Cretaceous system of the Rocky Mountain region[2] will arouse the interest of all geologists who have worked with these strata. He contends that, "The geology of the Rocky Mountain Upper Cretaceous is relatively simple" (p. 901), but reiterates that "the present nomenclature of the Upper Cretaceous is very confusing and should be revised and simplified" (p. 912). These objectives are to be attained through selection of "a system of names chosen to fit genetic conditions and mappable lithologic units" (p. 899). The chief beneficiaries of this clarification are to be "oil geologists from California and the Mid-Continent, who are now entering the Rocky Mountain area" (p. 903). That Mr. Bartram has limited his discussion only to those formations likely to be of concern to petroleum geologists, is attested by exclusion of the strata above the tongue of Fox Hills sandstone from his Figure 2, yet they are much involved with it as the upper part of the Eagle is with the Virgelle. No recognized portion of the system can be omitted logically from any consideration of its revision.

The method of Bartram's proposal is met at the very beginning with a fundamental condition with which geologists have been confronted always: namely, horizontal time lines (faunal zones) and diagonal lithologic units.[3] This difficulty is recognized by Mr. Bartram (p. 910) but its import with regard to his proposition is not discussed adequately. Furthermore, both the faunal zones and the rock units may be transitional. Many combinations are possible; and the abundance of names in the Rocky Mountain Cretaceous is the response of the geologists to the recognition of the kaleidoscopic changes which resulted in so many variations. If, in addition to following the rules for the classification and nomenclature of rock units, due allowance be made for the scientific rule of priority of name and consideration be given to the suitability of the type section, and if, in addition to this, emphasis be placed on genetic conditions, and some further allowance be made for tradition and personal or section prejudice, the task appears truly formidable. An additional difficulty is that our knowledge of the Cretaceous is still incomplete.

When the region of Cretaceous rocks (Bartram, Fig. 1) is regarded as a whole there is some duplication of names, to be sure, and some of these names have outlived their usefulness. Newcomers whose previous engagements have been confined to single districts or even states may find their initial efforts toward quick comprehension of the entire problem resulting in apparent complexity. Confusion of this type is illustrated, in my opinion, by Bartram's Figure 2, which telescopes countless stratigraphic details from southern Colorado to northern Montana into a single plane. Naturally, stratigraphic

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[2] John G. Bartram, "Upper Cretaceous of Rocky Mountain Area," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 7 (July, 1937), pp. 899–913.

[3] See W. T. Lee, "Relation of the Cretaceous Formations to the Rocky Mountains in Colorado and New Mexico," *U. S. Geol. Survey Prof. Paper 95C* (1916), Fig. 12, p. 19.

relations are more complicated in some areas than in others, but within any single district of the Rocky Mountain Cretaceous conditions are not troublesome. For example, in Montana, with the exception of the Dakota-Kootenai problem, they are so simple as to be almost diagrammatic.[4] This is due to the small number of major units and to the continuity of the formations, whereas in Wyoming and Colorado they are interrupted by mountain uplifts. Consequently, in the latter states the stratigraphic terminology for each intermontane basin shows "unnecessary duplicating and overlapping of geologic names." The correction of such local situations presumably will not be difficult. However, the development of a simplified terminology for the western Upper Cretaceous system is a more profound matter, and difficulty will arise in attempting to integrate numerous sets of clear stratigraphic relations into an even more simple regional picture. The problem is two-fold: a nomenclature for the thick body of marine shale on the east side of the basin, applicable also to the west-thinning shale tongues, and a nomenclature for the east-thinning "sand" wedges, such that it "will indicate the position of any individual one of the four shale units or any combination of two or three adjoining units."[5] It may be stated more or less categorically that regionally the Cretaceous stratigraphy is probably too complex to lend itself to over-simplification of this sort.

This does not mean that progress in simplification of the Cretaceous nomenclature is impossible. Indeed, an important step toward the solution of the nomenclature of the east-thinning wedges has been made by the United States Geological Survey in applying group names of rather loose time significance. This practice is best illustrated by the use of the name "Mesaverde group." See *U. S. Geol. Survey Bull. 819* (1931), Pl. 3; *Bull. 793* (1928), Pls. 3, 4, 15; *Bull. 851*, Pl. 4; and *Bull. 510* (1912), Fig. 3, for a west to east series of stratigraphic diagrams drawn longitudinally through a single wedge in Utah and Colorado for a distance of more than 200 miles. *U. S. Geological Survey Prof. Paper 95C* (1916), Fig. 21, p. 51, continues them eastward from Grand Mesa to Colorado Springs. This paper also contains several north-south sections. These diagrams also show how complex such a great mass may be. Aside from the regressive littoral sandstones which commonly form the base, the bulk of the wedge is made up of continental deposits seldom containing more than 40 per cent sandstone, and the term "sand wedge" is a misnomer.

The writer believes that more complete understanding of the formational relations of the Rocky Mountain Cretaceous system can be obtained by the construction of at least three north-south stratigraphic diagrams from New Mexico to Montana through the base, middle, and tips of the east-thinning "sand wedges." Such a series would show the areas of simple and complex conditions and their relations to areas of greatest overlapping of names, and possibly the reason therefor; areas of unknown conditions and "problem"

[4] See Eugene Stebinger, "The Montana Group of Northwestern Montana," *U. S. Geol. Survey Prof. Paper 90* (1915), Fig. 9, p. 67.
———, "Oil and Gas Geology of the Birch Creek-Sun River Area, Northwestern Montana," *U. S. Geol. Survey Bull. 691E* (1919), Pl. 18, p. 114.

[5] Quotation from Mr. Bartram's manuscript as delivered before 22nd Annual Meeting at Los Angeles, California, March, 1937, and before Rocky Mountain Association Petroleum Geologists at Denver, Colorado, April, 1937, but not included in his published paper.

areas would be defined; they would suggest the source of the "sand wedges" and thereby contribute pertinent data toward our knowledge of genetic conditions. Indeed, they might show that some local revision may do much to releave confusion, or that the time for definitive revision of the nomenclature is not yet at hand. Conceivably, if the diagrams assist in locating the approximate embouchures of the great streams affluent to the Upper Cretaceous sea, it may be possible to devise a system of names for them, as is done for ancient continents or extinct glacial rivers and lakes, which might be extended to their deposits, thus defining them geographically as well as genetically. Some such approach may be advisable if the proposed revision of the nomenclature indicates the necessity for new names.

CHARLES E. ERDMANN

UNITED STATES GEOLOGICAL SURVEY
DENVER, COLORADO
November, 1937

CORRECTION

WATER-INSOLUBLE RESIDUES

In the October *Bulletin*, in the article, "Water-Insoluble Residues in Rock Salt of Louisiana Salt Plugs," by Ralph E. Taylor, the following changes should be made.

Page 1271, Table I, column 3, under Avery Island: "7.90" should be 0.790.

Page 1285, line 2 from bottom: "$\overline{01\bar{1}1}$" should be $\overline{10\bar{1}1}$; and "$\overline{01\bar{1}2}$" should be $\overline{01\bar{1}1}$.

Page 1293, line 3 from bottom: "borosilicate" should be *borate*.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 12 (DECEMBER 1937), PP. 1595-1604

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available to members and associates.

"Erdgeschichte und Bewegungsbild der Erde" (Earth History and Crustal Movements). By S. VON BUBNOFF, Greifswald. *Zeitschrift für die Gesamte Naturwissenschaft*, Heft 5 (1936), pp. 185–204.

Tectonic investigations of individual areas may lead to the recognition of patterns of crustal behavior. Whenever it is found that provinces of a certain type tend to experience certain kinds of events, we have the basis for laws that need to be formulated precisely, in order to serve as guides for later investigations. This method of tectonic research is to be thought of as supplementary to the more common method, which consists of discussing crustal materials and their possible manners of yielding, and which proceeds on the basis of laboratory experiments and of the generally valid laws of physics and chemistry. Geology is in fact distinguished by the condition that it must be pursued by historical, as well as by mechanical, methods.

Since the historical method is still in its infancy, Professor Bubnoff undertook the compilation of the material for his *Geologie von Europa*[1] in an effort to recognize the areas that have acted as tectonic units in the course of European geologic history, and to determine types of movement that they have undergone. In the brief paper here under review he summarizes what he has learned,

(a) as to the types of structural unit present in the crust of Europe;
(b) as to the types of movement experienced by the various units.

In thinking of structural units we must distinguish between horizontal and vertical classifications of the crust. The horizontal classification preferred by Bubnoff is that into shields, shelves, and geosynclines.

The shields are those homogeneous parts of the crust that, after solidification (folding, gneiss development), have not again suffered any intense deformation but have tended steadily upward and have been covered, at most, for brief periods by shallow seas. As will be shown later, we may distinguish between shields of the first and second order.

Shelves are units that have remained persistently as low lands or shallow sea. We may distinguish stable and labile shelves: stable, if they sink rarely and slightly and are highly resistant to orogenic forces; labile, if they have thicker and less discontinuous sedimentary blankets, and yield more or less readily to orogenesis. The Russian plain, with 300 to 400 meters of post-Cambrian sedimentary rocks, represents the former; the North German plain, with 7,000 meters of Mesozoic-Tertiary strata, the latter.

Geosynclines are the most mobile parts of the crust, changing in the course of time from deep, in part abyssal, seas to high mountains. They are in a sense evanescent, since folding changes them to shields or shelves. In distinguishing between geosynclines and labile shelves it should be noted that submarine volcanic eruptions are prominent in the history of the former.

[1] In the series *Geologie der Erde*, published by Gebrüder Borntraeger, Berlin, (1926–36).

The vertical classification of the crust gives us likewise three units: basement, substructure, superstructure (Tiefbau, Unterbau, Oberbau). For the first type we may think of areas of pre-Cambrian gneiss; for the second, of the Variscan mountain masses of central Germany; for the third, of the flat-lying, unmetamorphosed sedimentary blanket of European plains and plateaus.

The two classifications may be combined, as follows.

1. Shields: basement (shields of the first order) and substructure (shields of the second order) with no superstructure or with a thin one.

2. Shelves: thin (stable) or thick (labile) superstructure above substructure or basement. Extreme examples of labile shelves may perhaps lack basement.

3. Geosynclines: at first, only a thick superstructure, changing after folding to a substructure. A new superstructure is acquired after peneplanation and renewed subsidence; it is absent from our young fold-mountains. Older basement and substructure in general not recognizable or restricted to small areas.

It remains now to analyze the types of movement of these elements of the earth's crust. Following Stille, many people now recognize two types of movements: broad, secular, structure-respecting movements (epeirogenic); and short-radius, episodic, structure-changing processes (orogenic). The distinction is a historic one, and doubtless a proper one, but unfortunately the definitions are not quite clear and the names—as Stille himself recognizes—are not entirely happy.

Thus, orogenesis means "mountain-making," but the term refers only to the production of mountain structure, not to that of mountain topography. Hence, it seems desirable to replace it by "tectogenesis," as Haarman suggested.

Epeirogenesis is a good term, on the other hand, but needs redefining so as to exclude a third set of movements, related to epeirogenesis but standing between it and orogenesis. These are basement folds (Argand), great-folds (W. Penck), special undations (Stille), or movements of the second order (Bubnoff).

On the basis of a most interesting analysis of certain features in the structural evolution of Europe, Bubnoff defines the three classes of movements.

Epeirogenic movements are broad warping movements, affecting groups of epeirogenic units in the same sense; they are autonomous, that is, independent of structure; they are reversible; they do not alter the structure though they prepare the way for its alteration; they are secularly active, though possibly to be thought of as summations of small movements rather than as large continuous movements.

Movements *of the second order* may similarly affect several tectogenic units, but they dismember epeirogenic units; they are not autonomous, but are structurally conditioned; they are not necessarily and in all cases reversible; they create new structures (in the ordinary sense) only locally, as in the boundary zones between the areas acting as units; finally, though secularly active, they may also have an episodic character, particularly in boundary zones.

Tectogenic movements are determined, as to form, by type of sedimentary material; they are incongruent, making structures that vary in the different

stories of the crust; and the deformation they produce is wholly irreversible. With reference to the structural types produced, we have, first, faulting in shields and stable shelves; second, fault-folding (German-type folding) in labile shelves; third, folding and nappe formation in geosynclines.

In a series of paleogeographic maps of Europe, the author shows that a definite cycle of events has been repeated at least five times since the pre-Cambrian. Thus the more or less north-south seas of the Cambrian changed to east-west seas in the Ordovician; the latter became differentiated into eastern and western seas during the Silurian, while sea-withdrawal and folding took place at its close (Caledonian movements). A similar cycle lasted from the Lower Devonian to the Upper Carboniferous, being ended by the Variscan movements; another from Lias to Upper Malm, a fourth from Lower to Upper Cretaceous, and a fifth from Paleocene to Lower Miocene. The sixth cycle, perhaps still incomplete, occupied the time since the Middle Miocene. On the basis of the uranium-lead chronology, each of these cycles is shorter than the preceding. Furthermore, the tectonic units affected have become steadily smaller.

With a statement of general principles, of which this review furnishes merely a brief summary that omits many interesting and pertinent explanations, the author chooses to close for the present. He glances at a possible dynamic interpretation for which he confesses a certain fondness, but decides that a discussion of it and its rivals may best be left to the future.

R. D. Reed

Los Angeles, California
October 12, 1937

"Occasional Papers on the Geology of Michigan." *Michigan Geol. Survey*, Geol. Ser. 34, Pub. 40 (Lansing, 1936). Pt. I, "The Pleistocene History of the Tahquamenon and Manistique Drainage Region of the Northern Peninsula of Michigan, with a Foreword Discussing the Glacial History of Michigan, and the History of the Great Lakes," by S. G. Bergquist, pp. 7–148; 16 figs., 27 pls. Pt. II, "The Pennsylvanian System in Michigan," by W. A. Kelly, pp. 149–226; 10 figs., 6 pls. Pt. III, "The Trenton and Black River Rocks of Michigan," by R. C. Hussey, pp. 227–57; 8 figs. Total, 260 pp. 6×9 inches. Cloth. Price, postpaid, $1.50. Pt. I, separate, $0.75. Pts. II and III each, separate, $0.50.

The three reports included in this bulletin are the first of a series contemplated by the Michigan Geological Survey, each of which will give a comprehensive study of representative formations in Michigan. They are detailed in scope and comprise the results of work done in several field seasons. Field work has been supplemented by thorough-going laboratory studies in the solution of a number of the problems encountered.

Part I of the "Occasional Papers" by Bergquist covers the Pleistocene geology of Alger, Luce, and Schoolcraft counties in the central part of the Northern Peninsula. These three counties extend from Lake Michigan on the south to Lake Superior on the north, and include the small cities of Manistique, Munising, Grand Marais, and Newberry. Most of the field work was carried on in connection with the Michigan Land Economic Survey and although the area covered includes such scenic spots as the "Pictured Rocks of Lake Superior," Tahquamenon Falls, the Dunes of Grand Marais, and the

"Big Spring," near Manistique, much of the terrane is cut-over timberland, muskeg, and inaccessible swampy lowland. Roads are scarce and mapping in this region is extremely difficult. The availability of airplane photographs and photographic mosaics added greatly to the excellence of the large maps in the report.

The Foreword is an outline of the glacial history of Michigan, with a short discussion of the various ice invasions, the development of the different morainic systems, and the history of the several stages of the Great Lakes. It is completed with a few paragraphs on the differential uplift which followed the glacial period and the positions of the hinge lines of uplift. This discussion is largely after Leverett and Taylor, with minor changes and modifications. The figures which accompany the discussion could have been somewhat improved as to uniformity of shading and quality of reproduction.

The main body of the report is preceded by a clearly stated synopsis and the usual introduction with adequate acknowledgments. The field work for this report was done in 1928, 1929, 1931, and 1932. In Chapter 1, the Tahquamenon Drainage System is discussed. This river heads in Luce County, traverses both Luce and Chippewa counties, and is finally discharged northeastward into Whitefish Bay in Lake Superior. The chapter also includes discussion of the Two-Hearted River System, the Little Two-Hearted River, the Sucker Basin, and the Shelldrake Drainage System along with lakes, swamps, and marshy tracts of the general region. An excellent "tip-in" geological map of the surface formations of Luce County accompanies the discussion. Chapter 2 is a similar treatment of the Manistique River Drainage System, whose principal river flows southwestward across Schoolcraft County and empties into Lake Michigan at Manistique. A map of Schoolcraft County, similar to that of Luce County in the previous chapter, is of particular interest because it shows the areas of Niagaran rocks in the county.

The glacial features of the region classified and described in Chapter 3 include the Trenary Till Plain, the Cooks Moraine, the Newberry or "Outer" Morainic System, the Munising or "Inner" Morainic System, the Crisp Point Moraine, and the Outwash Plains associated with the Munising Moraine. Most of these features are shown on a geological map of Alger County, which accompanies this chapter. The map also outlines the outcropping beds of Lake Superior sandstone fringing the lake shore near Munising where its ledges cause the many scenic waterfalls of that region.

Many of the surface features of the Tahquamenon-Manistique Drainage Basin are lacustrine in origin, and in Chapter 4, the features of glacial Lake Algonquin, Nipissing Great Lakes, and Post-Nipissing Lakes are discussed in order. In Chapter 5, the report is concluded with a complete discussion of the results of recent aeolian activity in the area. The widespread and well developed dunes are subdivided into three major groups: (1) shore dunes along Lake Superior, (2) dunes of the poorly drained, marshy, lowland plains of the main drainage ways, and (3) shore dunes along Lake Michigan. At the end of the report is a composite geological map of the Surface Formations of Alger, Luce, and Schoolcraft Counties; a Location Map of the Major Features of these counties; a bibliography and a well prepared index.

This report is of particular interest to the petroleum geologist because it contains accurate and carefully prepared maps of surface formations in a northern Michigan region, much of which is not easily accessible. The numer-

ous half-tone cuts in the report are well done and add to the clarity of the subject matter. Possibly, a reader unfamiliar with Michigan would find greater use for the Location Map of the Major Features if it were at the front of the report instead of at the end. The report is a well rounded-out treatise on the central part of Michigan's northern peninsula and adds greatly to the geological literature of that region.

Part II of the "Occasional Papers" by Kelly is a summary treatment on the Pennsylvanian System of Michigan. It takes up in a systematic fashion the history of all previous geological work on this system in Michigan, cites changes in classification and viewpoint from worker to worker, and sets forth methodically the details of occurrence of each formation and member within the system as now classified by him. Throughout this report the details of painstaking field study are manifest, and theories of cyclical sedimentation in coal-bearing rocks are frequently used in reaching final conclusions.

The historical review is accompanied by plates I and II, which show the changes in outline of the known areal extent of Pennsylvanian rocks in Michigan, as understood from 1861 to 1932. Table I traces ten stages of Pennsylvanian Nomenclature in Michigan from 1861 to 1933.

In chapters 2–4, inclusive, the formations of Pennsylvanian Age in Michigan are described in ascending order. These are the Parma sandstone; the Saginaw group with Pre-Verne, Verne, and Post-Verne Cyclical members; and the Grand River group with the Woodville, Eaton, and Ionia sandstones; and the "Rock Beds" of Central Michigan.

The Parma sandstone is discussed in Chapter 2 as to name, sources of study, stratigraphic relations, lithology, correlation, thickness and the local details in Jackson and Calhoun counties, where it crops out. A one-inch-to-the-mile map of its occurrences is included with the discussion. At the beginning of Chapter 3 is a map of the Southern Peninsula, showing outcrop and mine localities of the Saginaw and Grand River groups, and the 1936 formation boundaries as outlined by Helen M. Martin. The Saginaw group is described under about the same headings as the Parma sandstone and several pages are given over to lists of fossil plants and fauna found within the group. After type sections at Grand Ledge, Eaton County, are given, the important localities of Verne formations are taken up in order from Arenac County, southward to Ingham County. This chapter also contains detail maps of Grand Ledge vicinity, of exposures near Corunna, of outcrops near Chester north of Charlotte, of exposures near Williamston; and columnar cross sections of the Verne limestone, sections of beds in the Grand Ledge area, columnar sections near Corunna, and columnar sections near Williamston. Tabulated sections showing the juxtaposition of plant and faunal species in individual districts also follow with the text.

In Chapter 4, a new name "Grand River Group" is given to the upper formation of the Pennsylvanian in Michigan. The Eaton sandstone and Ionia sandstone members crop out along the Grand River valley between Ionia and Grand Ledge, but the Woodville type section is found near Jackson. According to Kelly, the basal Eaton sandstone beds "are post-Saginaw in age, but their true stratigraphic relations to the Woodville sandstone, the Ionia sandstone, or other strata of the Grand River group cannot be determined." Although he places the gypsiferous "Red Beds" at the top of the highest Grand River, he hesitates to include them in that group because of

the marked difference in lithology. The chapter is concluded by a brief resumé of structure observed in the rocks of the Pennsylvanian. A register of localities, a bibliography, and an adequate index complete the report.

The value of this report to the petroleum industry is that it brings together all available data on exposures of the rock formations first penetrated by the drill in central Michigan. The individual beds of the Pennsylvanian are difficult to correlate from well to well, and the conclusions of an intimate field study of this type are particularly helpful in "core testing" for structure. Much of the "core testing" undertaken here commences in the Coal Measures, and although individual beds of these formations do not afford reliable "markers" for detailed structure work, a knowledge of their characteristics is indispensable to distinguish between them and the Marshall section below.

The maps and cross sections are clearly drawn and can be easily taken into the field for comparative examination. The drafting on them is uniform in character and the amount of reduction is not so great as to destroy legibility. The scaling is for the most part exact and well indicated.

Part III of the "Occasional Papers" by Hussey brings together a compiled work on the Trenton and Black River Rocks of Michigan. The principal outcrops of these rocks are found in the western part of the Northern Peninsula within a belt about twenty miles wide extending in a general northeast direction past the towns of Escanaba and Rapid River. Scattered outcrops exist north of this locality near Trenary, and the rest of the exposures are found on Drummond Island, in the eastern part of the Northern Peninsula.

This short report consists largely of a description of sections, with detail on the individual beds and their characteristic fossils. Each of the 28 field stations described in the report is listed by number. These were visited by expeditions of the University of Michigan in 1927–28.

The report is prefaced by a brief historical review, two paragraphs on the general distribution and attitude of the rocks, and a short discussion on the relation of the Trenton to the Richmond. The detailed description of sections starts with the Black River, is concluded with the Trenton, and several clear half-tone cuts of outcrop localities follow along with the description. At the end of the report is an exhaustive bibliography, a list of numbered field stations, and an index.

The outcrops of Trenton and Black River rocks in the Northern Peninsula are far removed from the principal drilling activity for oil and gas, and these beds thicken and change markedly southward into the center of the basin. However, the "Trenton" rocks are potentially a source of deeper oil in Central Michigan and as future deep drilling goes on, this report will become more and more useful as a reference for correlation.

R. B. Newcombe

Mount Pleasant, Michigan
October 20, 1937

"The Centennial Geological Map of Michigan," *Geological Survey Division, Michigan Department of Conservation*, Pub. 39, Geol. Ser. 33, Ann. Rept. for 1936 (October, 1937). 2 sheets showing areal geology and cross sections. State Geologist, Lansing, Michigan. Price, $1.50 per set: $1.00 for Southern Peninsula and $.50 for Northern Peninsula. Paper only.

The Centennial Map of Michigan has been published by the Geological

Survey Division of the Michigan Department of Conservation, as a culmination of 100 years of geological exploration and exploitation of the mineral resources of the state. Prepared on a scale of 8 miles to the inch, accompanied by two cross sections and employing a large number of colors and patterns, the map shows the areal distribution and indicates the stratigraphic and structural relations of 44 subdivisions of the Paleozoic rocks, and in a remarkably comprehensive legend, Miss Helen Martin, who compiled the map, gives a brief description of the rocks of the state and shows how field workers have further subdivided the major units into formations, members, and individual beds, to which they have applied 143 distinct names. In this legend also are indicated the principal economic resources found in the various geologic units.

In the preparation of data for this map all available sources of information were used, including the files of the Geological Survey, the University of Michigan and Michigan State College, and logs and samples from more than 5,500 wells, in addition to much detailed information furnished by mining, oil, and other industrial operators.

R. A. Smith, State geologist, under whose direction this map was prepared, laid down the policy that this map should not be a presentation of any one opinion concerning the sequence of distribution of the rocks of the state, but should be a complete compendium of readily available information, bringing into focus all the work done by the scores of geologists who have contributed to the knowledge of Michigan geology during the century in which the survey has existed, and furnishing a basis for further effective and efficient exploration of the geology of the state. This objective has been well attained, and the map will prove to be a desirable and useful part of the equipment of all those interested in the geology of Michigan either from an academic or an economic standpoint.

B. F. Hake

Saginaw, Michigan
November 4, 1937

RECENT PUBLICATIONS

ARGENTINA

"Observaciones estratigráficas en el Norte Argentino" (Stratigraphy of Northern Argentina), by Otto Schlagintweit. *Bol. Inform. Petroleras* (Buenos Aires), Vol. 14, No. 156 (August, 1937), pp. 1–49; 24 photographs.

AUSTRALIA

*"A Contribution to the Permian-Upper Carboniferous Problem and an Analysis of the Fauna of the Upper Palaeozoic (Permian) of North-West Basin, Western Australia," by H. G. Raggatt. *Records of the Australian Museum* (Sydney), Vol. 20, No. 2 (August 27, 1937), pp. 150–84.

BRAZIL

*"*Asphaltos e Sapropelitos* (Asphalts and Sapropelites), by S. Fróes Abreau and R. Roquette. Instituto Nacional de Technologia, Rio de Janeiro (1937). 84 pp. Contains a page of summary in English. Report composed of four papers presented before the 3d South American Chemical Congress in July, 1937. 1. "Bituminous Sandstone of Anhemby" is based on the study of

samples sent the laboratory. 2. "Taipú-Mirim Asphalt" shows that the Marahú River region may be suited for petroleum research. 3. "Sapropelitic Limestone from Codó" gives some results about the nature and origin of organic matter. 4. "Sapropelite from Jucú" suggests the possibility of oil pools being generated by recent sapropelitic rocks.

CALIFORNIA

*"Development of El Segundo Oil Field," by L. E. Porter. *Petrol. World* (Los Angeles), Vol. 34, No. 10 (October, 1937), pp. 39–44, 54; 6 figs.

*"The Wilmington Oil Field," by E. J. Bartosh. *Oil World* (Los Angeles), Vol. 30, No. 20 (October 20, 1937), pp. 4–9; 7 figs.

CANADA

*"Turner Valley Gas and Oil Field of Alberta," by G. S. Hume. *Min. and Met.* (New York), Vol. 18, No. 371 (November, 1937), pp. 501–05; 5 figs.

CHINA

*"Das Gebiet des Yangtze-Deltas mit den Nanking-Bergen" (The Region of the Yangtze Delta and the Nanking Mountains), by Hans Becker. *Geol. Rundschau* (Stuttgart), Bd. 28, Heft 5 (October, 1937), pp. 385–406; correlation table of Carboniferous and Permian, geologic section, and tectonic map (folded insert).

FRANCE

*"Carte structurale de la partie nord du champ petrolifère de Pechelbronn" (Structural Map of the Northern Part of the Pechelbronn Oil Field), by R. Schnaebele and J. Walther. Separate from 2d World Petroleum Congress (Paris, June, 1937). 3 pp. text, map sheet 16.5×21 inches.

*"Possibilités de pétrole dans le Trias Lorrain" (Possibilities of Petroleum in the Triassic of Lorraine), by Ch. Finaton. *Rev. Petrol.* (Paris), No. 753 (October, 1937), pp. 1381–85; geologic map and sections.

GENERAL

*"The Principle of Petroleum Engineering," by M. L. Haider. *Oil Weekly* (Houston, Texas), Vol. 87, No. 8 (November 1, 1937), pp. 19–28; 12 figs.

**Bibliography and Index of Geology Exclusive of North America, Volume 4–1936*, by John M. Nickles, Marie Siegrust, and Eleanor Tatge. Published by the Geological Society of America, 419 West 117th Street, New York (1937). 480 pp.

*"Les donnes scientifiques d'un Forage de Prospection et leur Interprétation" (The Scientific Data of Exploratory Drilling and Their Interpretation), by W. Tiraspolsky. *Bull. Assoc. Fran. Tech. Pétrol.* (Paris), No. 40 (October 1, 1937), pp. 17–33.

*"Aerial Photographer Is Rendering Valuable Service to Oil Industry," by R. A. Bowen, *Oil and Gas Jour.* (October 28, 1937), pp. 28–29; 3 photos.

*"Geological Application of Oriented Coring," by A. B. Patterson and J. K. Butler, *Ibid.*, p. 46.

*"A Method of Determining Porosity: A List of Porosities of Oil Sands," by D. B. Taliaferro, Jr., T. W. Johnson, and E. J. Dewees. *U. S. Bur. Mines Rept. Investig. 3352* (September, 1937). 24 mimeogr. pp., 2 figs.

GERMANY

*"Die Foraminiferen des deutschen Lias" (The Foraminifera of the German Lias), by Adolf Franke. *Abh. Preuss. Geol. Landesanstalt* (Berlin), Neue Folge, Heft 169 (1936). 139 pp., 12 fossil pls., 2 text figs.

*"Étude comparative des dômes pétrolifères du Hanovre et des structures Tunisiennes" (Comparative Study of the Oil Domes of Hanover and the Tunisian Structures), by Alfred Roux and Marcel Solignac. *Annal. Combustibles Liquides* (Paris), No. 3 (May–June, 1937), pp. 447–509; 13 pls.

GREAT BRITAIN

The First Hundred Years of the Geological Survey of Great Britain, by John Smith Flett. The Director of Publications, H. M. Stationery Office, London (1937). Price $2.15.

GUATEMALA

*"Algo sobre Geologia y Petrografia del Valle de la Ermita" (Geology and Petrography of the Ermita Valley), by José H. Mendez Z. *Ingenieria Nacional* (Guatemala), Vol. 3, Nos. 6–7 (June–July, 1937), pp. 141–42.

HUNGARY

*"Das Mineralölvorkommen von Bükkszék und die staatlichen geologischen Forschungen in den nördlichen Randegebirgen der Grossen Ungarischen Tiefebene" (Petroleum Occurrences at Bükkszék and the State Geological Investigations in the Northern Randgebirgen of the Great Hungarian Deep Plain), by L. v. Lóczy. *Petroleum Zeits.* (Berlin), Vol. 33, No. 39 (October 1, 1937), pp. 1–10; 7 figs. including paleogeographic and geologic maps and cross sections.

ILLINOIS

*"Correlation Problems in the New Illinois Basin Fields," by Lewis E. Workman and Alfred H. Bell. *Illinois Geol. Survey Inform. Cir. 22* (October 4, 1937). 2 pp. Also, *Oil Weekly* (October 25, 1937), p. 19.

*"Recent Discoveries in Southern Illinois," by Theron Wasson. *Oil and Gas Jour.* (Tulsa), Vol. 36, No. 24 (October 28, 1937), pp. 20–21, 40; 2 figs. from A.A.P.G. Mid-Year Meeting, Pittsburgh, October 14–16.

*"Featuring Illinois Basin." Special number, *Oil and Gas Jour.* (October 28, 1937). Contains articles on field services, engineering, geology, crude analyses, folded map.

*"New Illinois Areas Outlined for Early Testing," by Alfred H. Bell. *Natl. Petrol. News* (Cleveland, Ohio), Vol. 29, No. 42 (October 20, 1937), pp. 25–26; 1 map.

*"Stratigraphic Studies of Pennsylvanian Outcrops in Part of Southeastern Illinois," by William A. Newton and J. Marvin Weller. *Illinois State Geol. Survey Rept. Investig. 45* (Urbana, 1937). 31 pp., 1 pl. 12 figs. Price, $0.25.

*"Subsurface Contour Map of the Illinois Basin," by Alfred H. Bell. *Illinois Geol. Survey* (1937). Shows structure on base of Mississippian. Folded sheet, 15×22 inches. Price, $0.25.

INDIANA

*"Indiana Portion of Basin Is Now Receiving Attention," by Ralph Esarey. *Oil and Gas Jour.* (October 28, 1937), pp. 108–16; 3 maps and stratigraphic table.

KANSAS

**Gorman's Petroleum Directory of Kansas* (October, 1937). Published and for sale by B. R. Gorman, Box 395, Tulsa, Oklahoma. 88 pp. Lists individuals and companies connected with production of petroleum. Price, postpaid, $1.00.

LOUISIANA

*"Lisbon Most Important Find in Region since Rodessa," by Brad Mills. *Oil Weekly* (Houston), Vol. 87, No. 8 (November 1, 1937), pp. 69–71; aerial photo and reservoir pressure map.

MARYLAND

*"The Upper Cretaceous Deposits of the Chesapeake and Delaware Canal of Maryland and Delaware," by Charles W. Carter. *Maryland Geol. Survey* (Baltimore), Vol. 13, Pt. 6 (1937), pp. 237–81; 6 figs., 5 pls.

MEXICO

*"Ligeras nociones sobre las regiones petroleras mexicanas" (Mexican Oil Region), by Enrique Diaz Lozano. *Ingenieria* (Mexico, D. F.), Vol. 11, No. 10 (October, 1937), pp. 383–94; folded map showing location of fields, 18×20 inches.

PERU

*"Sobre el 'Gas Natural' del campo petrolifero de Zorritos" (Natural Gas in the Zorritos Oil Field), by Georg Petersen. *Bol. Soc. Geol. Peru* (Lima, Apartado 2559), Vol. 8, No. 1 (1936). 8 pp.

*"Sobre la geologia de la region de Zorritos" (Geology of the Zorritos Region), by Georg. Petersen. *Ibid.*, No. 2 (1936). 57 pp., 2 line drawings, 9 photographs, 4 tables, and geologic map of region of oil fields (26×18 inches).

PHILIPPINES

*"Das Erdöl und seine Verwandten in den Philippines" (Petroleum and Related Substances in the Philippines), by K. A. F. R. Musper. *De Ingeniem in Nederlandsch-Indië*" (Batavia-Centrum), Vol. 4, No. 8 (August, 1937), pp. 141–57, 6 figs.

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

**Journal of Paleontology* (Tulsa, Oklahoma), Vol. 11, No. 7 (October, 1937).

"Ordovician Cephalopods from the Black Hills, South Dakota," by A. K. Miller and W. M. Furnish.

"Lower Neocomian Fossils from the Miquihuana Region, Mexico," by Ralph W. Imlay.

"Systematic Position of the Olenellidae (Mesonacidae)," by Frank Raw.

"*Eupachycrinus* and Related Carboniferous Crinoid Genera," by Edwin Kirk.

"New Mollusks from the Choctawhatchee Formation of Florida," by W. C. Mansfield.

"New Genera and Species of Tetrapods from the Karroo Beds of South Africa," by Everett Claire Olson and Robert Broom.

"*Taeniaster* in Pennsylvania," by Bradford Willard.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 12 (DECEMBER, 1937), PP. 1605-1616, 1 FIG.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Francis Dashwood Bode, Sierra Madre, Calif.
Albert Gregersen, Chester Cassel, James M. Hamill
Ernest Kundig, Maracaibo, Venezuela, S.A.
L. Kehrer, Alfred P. Frey, Victor Oppenheim
John F. Magale, Shreveport, La.
Albert E. Oldham, W. C. Spooner, H. N. Spofford
Rufus McBride Smith, Kansas City, Mo.
Glenn G. Bartle, W. A. Waldschmidt, F. M. Van Tuyl

FOR ASSOCIATE MEMBERSHIP

Kilburn Elie Adams, Jr., Oklahoma City, Okla.
J. N. Troxell, V. C. Scott, H. H. Arnold, Jr.
David A. Banta, Pittsburgh, Pa.
C. H. Dresbach, Walter J. Osterhoudt, A. G. Nance
Charles Vincent Foster, Borger, Tex.
Ivan J. Fenn, Carl C. Anderson, Raymond Sidwell
Lawrence Frank Guseman, Houston, Tex.
C. C. Zimmerman, L. A. Scholl, Jr., John C. Miller
Richard Marion Holland, Jr., Lafayette, La.
C. E. Decker, Burr McWhirt, V. E. Monnett
Donald Frost Newell, Corpus Christi, Tex.
Charles E. Decker, V. E. Monnett, G. E. Anderson
William Thomas Rothwell, Jr., Princeton, N. J.
W. T. Thom, Jr., Edward Sampson, Albert O. Hayes
George Frederick Shepherd, Bartlesville, Okla.
T. E. Weirich, T. K. Knox, D. E. Lounsbery
Robert Briggs Totten, Shreveport, La.
Joseph Purzer, Clarence O. Day, T. E. Weirich

FOR TRANSFER TO ACTIVE MEMBERSHIP

Kenneth H. Ferguson, Houston, Tex.
Roderick A. Stamey, A. J. Bauernschmidt, Jr., Lon D. Cartwright, Jr.
Arthur G. Munyan, Atlanta, Ga.
D. J. Jones, P. G. Nutting, C. D. Hunter

TWENTY-THIRD ANNUAL MEETING, NEW ORLEANS
MARCH 16-18, 1938

CHAIRMEN OF COMMITTEES

General chairman, R. A. Steinmayer, Tulane University, New Orleans
Technical program, C. L. Moody, Ohio Oil Company, Shreveport
Finance, R. A. Steinmayer
Entertainment, Carroll E. Cook, 1403 Octavia Street, New Orleans
Reception, C. I. Alexander, Magnolia Petroleum Company, Lake Charles
Publicity, C. K. Moresi, Civil Court House, New Orleans
Hotels, J. Edward Lytle, 930 Main Street, Hattiesburg, Mississippi
Field Trips, Roy T. Hazzard, Gulf Refining Company, Shreveport
Transportation, Tatham R. Eskrigge, 1326 Harmony Street, New Orleans
Golf, Donald Goodwill, Jr., Department of Conservation, New Orleans

In addition to the names of committeemen published in the November *Bulletin* (page 1507), the following appointments have been made.

Finance committee, R. A. Steinmayer, chairman

E. L. Caster	C. R. McKnight	G. D. Thomas
C. C. Clark	George W. Schneider	

Entertainment committee, Carroll E. Cook, chairman

W. M. Barret	L. S. Harlowe	L. R. McFarland
S. P. Borden	W. K. Link	E. H. Thaete
V. P. Grage	A. M. Lloyd	M. E. Wilson
S. G. Gray	J. F. Mahoney	

Field trips, Roy T. Hazzard, chairman

B. W. Blanpied	Urban B. Hughes	Paul T. Seashore
Martin N. Broughton	James H. McGuirt	

TECHNICAL PROGRAM

The technical program will feature the oil and gas geology of the Gulf Coast states. The following papers dealing with related problems are now in course of preparation and they constitute a tentative list for the technical program.

WARREN B. WEEKS, "South Arkansas Stratigraphy with Special Emphasis on the Older Coastal Plain Beds"
M. C. ISRAELSKY, "Cretaceous and Late Comanche Stratigraphy of the Arkansas-Louisiana-East Texas Area"
R. T. HAZZARD, A. M. LLOYD, C. I. ALEXANDER, "North-South Cross Section, Arkansas to the Gulf of Mexico"
J. S. IVY, "The Rodessa Field, Louisiana, Texas, Arkansas"
A. M. LLOYD and R. T. HAZZARD, "Resumé of Louisiana Upper Cretaceous Oil Fields"
URBAN B. HUGHES, "The Miocene-Oligocene Problem in Smith County, Mississippi"
B. W. BLANPIED, "Salt Mountain Limestone, Alabama"
B. W. BLANPIED and R. T. HAZZARD, "Stratigraphy of Wayne County, Mississippi"
B. W. BLANPIED and R. T. HAZZARD, "Structure and Stratigraphy of the Hatchetigbee Anticline and Jackson Fault, Alabama"
E. B. HUTSON, "Cotton Valley, Louisiana"
SIDNEY PACKARD, "Sligo Field, Louisiana"
V. P. GRAGE and E. F. WARREN, "The Sugar Creek-Sligo Structure, Louisiana"
C. C. CLARK, "Sugar Creek Gas Field, Louisiana"
A. F. CRIDER, "Bellevue Dome, Louisiana"
G. D. THOMAS, "Carterville-Shongaloo-Sarepta Area, Louisiana"
H. R. KAMB, "Bethany-Waskom Gas Area, Texas and Louisiana"

WARREN B. WEEKS, "Schuler Field, Union County, Arkansas"
R. T. HAZZARD, "Resumé of Geophysical Activities in North Louisiana and South Arkansas"
DEAN METTS, "The Roanoke Field"
W. C. SPOONER, "History of Development of Geologic Knowledge of North Louisiana and South Arkansas with Particular Reference to Well Sampling and Use of Schlumberger Logs"
H. N. TOLER, "The Jackson Gas Field, Mississippi"

Papers on the Zwolle and Converse chalk-rock fields of Louisiana and the Midway salt dome of Lamar County, Mississippi, are at present prospects.

A review of recent developments in North Louisiana and South Arkansas will be presented by H. K. SHEARER. South Louisiana will be discussed by R. B. GRIGSBY. A contribution to salt-dome terminology will be made by RALPH E. TAYLOR.

ARTHUR C. MUNYAN of the Georgia Geological Survey will contribute a paper on the Coastal Plain of Georgia, and KENDALL E. BORN will speak on new developments in Tennessee.

Several papers are expected dealing with the geology of the Coastal Plain of Texas. Titles and authors will be announced later.

Among the papers now being prepared in the Mid-Continent region are the following.

ALLEN W. TILLOTSON, "The Olympic Pool, Hughes and Okfuskee Counties, Oklahoma"
GEORGE NORTON, "The Permian Red-Beds of Kansas"
GAIL CARPENTER, "Geology of the Bemis Pool, Kansas"
ROY HALL, "History of the Central Kansas Uplift"
MARVIN TAYLOR and JOHN GARLOUGH, "Geology of the Southwest Kansas Gas Area"
F. B. PLUMMER and R. C. MOORE, "Stratigraphy and Structure of the Older Carboniferous Rocks on the Llano Uplift in Central Texas"

From the Rocky Mountain area is expected a paper by W. T. NIGHTINGALE on non-marine Tertiary oil in the Green River Basin country and a discussion by FRANK W. DEWOLF of the Paleozoic beds encountered in the Baker-Glendive well in southeastern Montana. Papers describing the Cut Bank field and reviewing recent developments throughout the Rocky Mountain area are in prospect.

Two of the papers that may be expected to represent California are the following.

R. G. REESE, "El Segundo Oil Field, Los Angeles Basin, California"
E. J. BARTOSH, "The Wilmington Oil Field, Los Angeles Basin, California"

Of general interest will be two papers specially contributed by the Society of Exploration Geophysicists. Papers emphasizing the relationship between geology and petroleum engineering will be found on the program. One or two contributions from the United States Bureau of Mines are now being sought in this connection. F. B. PLUMMER will have a paper on oil reservoirs.

Program contributions from abroad for delivery at New Orleans will be well received. HOLLIS D. HEDBERG is preparing a paper on the geology of the southern Caribbean which should prove of widespread interest.

Members contemplating taking part in the technical program at the New Orleans convention should communicate with the nearest program committee member, as announced in the November *Bulletin;* with Association headquarters, Box 979, Tulsa, Oklahoma; or with C. L. Moody, Box 1129, Shreveport, Louisiana.

In order to insure their inclusion in the printed programs for convention use it is desirable that abstracts of papers to be presented be in chairman Moody's hands by February 1.

FIELD TRIPS

The following tentative plans are outlined for field trips.

1. *South Mississippi. Two-day post-convention trip.*—Leaders, Urban B. Hughes and B. W. Blanpied. Smith and Wayne counties. Study of field relationship of the Vicksburg and Chickasawhay formations. This trip is planned primarily for Gulf Coast paleontologists and geologists who may be interested in the "so-called" Oligocene-Miocene problem. Travel by bus, leaving New Orleans Friday afternoon, spending Saturday and Sunday in the field, and returning Sunday night to New Orleans. Headquarters at Laurel, Mississippi. Provision can be made to handle a maximum of 75 individuals. Cost of trip covers bus fare only.

2. *Salt Mine. One-day post-convention trip.*—Leader, James H. McGuirt. Avery Island Botanical Gardens and visit to salt mine. A trip which probably will be very interesting to visiting members and families who previously have not had opportunity of seeing South Louisiana. It is planned to make this trip by automobiles on Saturday following the convention. Drivers of personal or company cars who plan to make the trip will be requested to take one or more passengers. Details of trip to be more fully arranged at a later date.

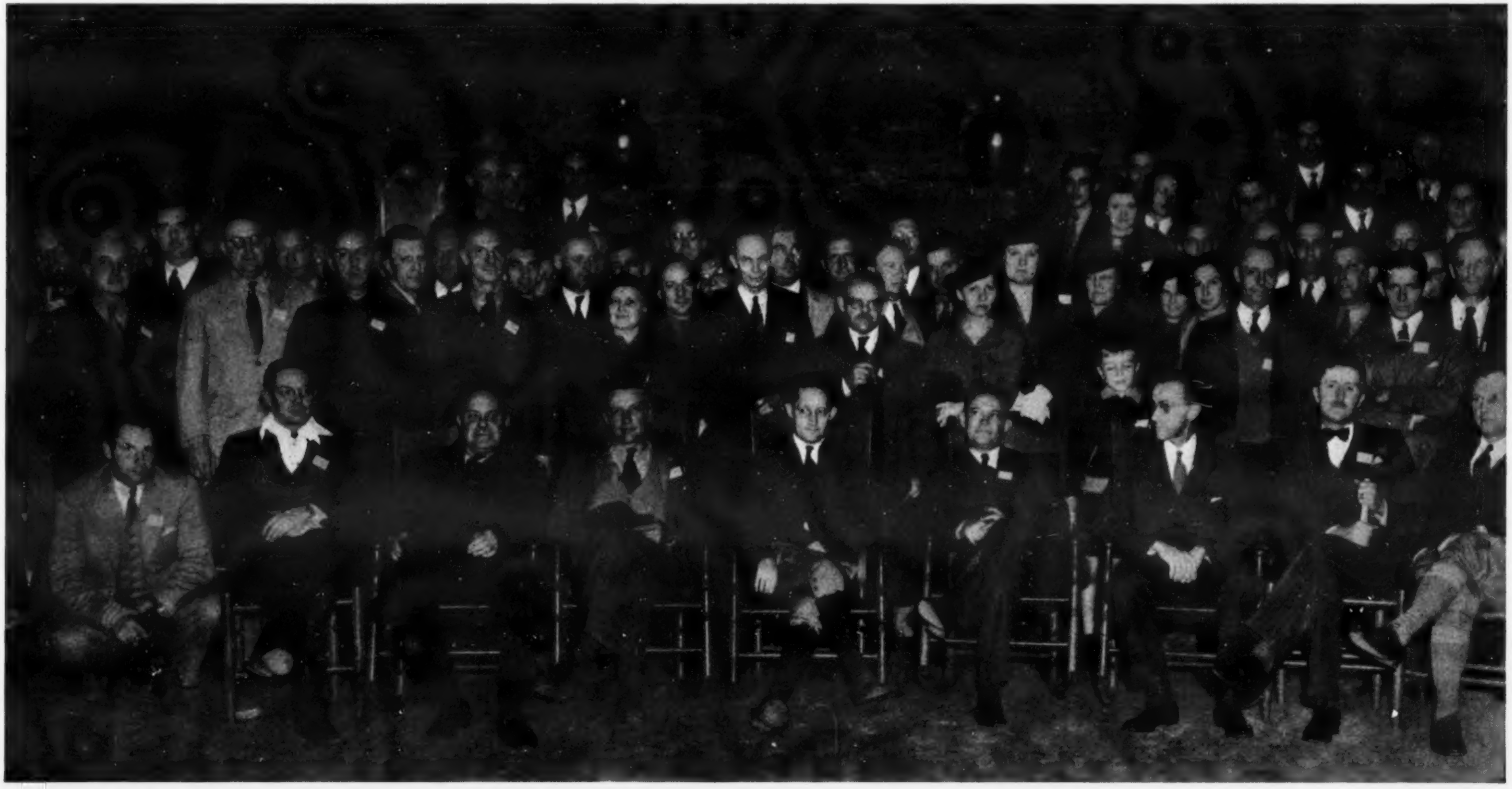
3. *Gulf Coast drilling operations. One-day post-convention trip.*—Leaders, Paul T. Seashore and M. N. Broughton. Mr. Stewart, division manager of The Texas Company, Shreveport, Louisiana, has very kindly consented to make provision for handling a maximum of 50 individuals for trip by speedboat to one of the Gulf Coast fields being developed by The Texas Company. This trip will be very interesting to members who are not acquainted with the type of drilling equipment and the procedure used by The Texas Company in its drilling operations in Gulf Coastal waters. Mid-day luncheon will be provided through courtesy of The Texas Company at one of its field camps. Details of trip to be more fully arranged at a later date.

4. *Sight-seeing, Gulf Coast oil fields. One-day post-convention trip*—Arrangements are to be made for a trip by automobiles for members who wish to secure a hurried picture of the geographical relationships and areal distribution of a number of the more accessible Gulf Coastal fields, under guidance of a Gulf Coast geologist who can summarize the more important features concerning each field visited. It is planned to make this trip on Saturday following the convention.

5. *Airplane trip over Mississippi Delta.*—Arrangements are to be made with the Delta Air Line for handling groups of 8 or more individuals who wish to make an airplane trip of several hours duration over the Mississippi Delta. These trips will be nominal in cost and can be made any time throughout the convention.

MID-YEAR MEETING, PITTSBURGH, OCTOBER 14-16, 1937

Mid-year, or fall, conventions of the Association are different. They are smaller than the annual meetings held in March. With no business meeting



Mid-year meeting of The American Association of Petroleum Geologists. Group on the pre-convention field trip, in the lodge at Endless Caverns, New Market, Virginia, October 11, 1937. Front row, left to right, in chairs: M. Gordon Gulley, in charge of field trips; L. P. Garrett, past-president; A. I. Levorsen, past-president; Ira H. Cram, secretary-treasurer; H. B. Fuqua, president; J. P. D. Hull, of Association headquarters; Paul H. Price, State geologist of West Virginia; Arthur Bevan, State geologist of Virginia.

and with a comparatively brief technical program, the fall meeting is an opportunity for visiting a petroliferous province or a locality that may be too far from the residence of the majority of members to justify the large annual meeting. It serves to uncover geological facts and to review development in one area and to make this information available for *Bulletin* publication. The fall meeting may be less formal, more carefree, even more enjoyable, if possible, than the official annual March meeting. It maintains the Association interest in one region, increases membership, and brings out new and more papers for the information of all members.

The Pittsburgh convention was such a meeting: comfortably small, technically important, scientifically profitable, thoroughly enjoyable. The technical program presented a pleasing combination of historical setting and current activity. Special interest was shown in the new development in the Illinois Basin, in the possibilities of deep production from the Oriskany formation in the Appalachian region, in geophysical methods of discovery and repressuring methods of recovery in old fields.

But to 80 geologists, including several ladies, perhaps the outstanding feature of the meeting was the wonderful pre-convention field trip, crossing the Appalachian Mountains into the Shenandoah Valley of Virginia, and recrossing them into West Virginia,—a spectacular unfolding of regional geology in two days. A post-convention trip into northwestern Pennsylvania was almost equally popular, visiting the historically interesting country of the oil pioneers: Titusville, the Drake discovery well, and the Bradford field, the home of water-repressuring for recovery of previously abandoned oil.

The entire arrangements committee, one and all, under the general chairmanship of Robert W. Clark, of the Gulf Oil Corporation, presented a well planned, fully enjoyable meeting.

The papers read at the meeting are as follows. It is planned to print them in early numbers of the *Bulletin*.

George H. Ashley, "History of Development and the Geologic Relationships of the Appalachian Fields"
L. L. Nettleton, "Gravity, Magnetic and Geologic Profile across the Appalachian Mountains"
L. E. Randall, "Seismograph Exploration in the Appalachian District"
Charles R. Fettke, "The Oriskany in Pennsylvania"
Robert C. Lafferty, "The Oriskany in West Virginia"
Wilbur H. Stout, "Petroleum Geology of Eastern Ohio"
C. A. Hartnagel, "The Medina and Trenton of Western New York"
Ben F. Hake, "Geological Occurrence of Oil and Gas in Michigan"
Theron Wasson, "Geological Occurrence of Oil and Gas in Illinois"
R. E. Stouder, "The Chester Formation of Western Kentucky"
Newell M. Wilder, "Results of Repressuring in Kentucky"

The registered attendance at Pittsburgh was 222: 101 members, 9 associates, 36 non-member women, and 76 non-member men.

At Charleston, West Virginia, a banquet was given by the Appalachian Geological Society, at the Ruffner Hotel, on the second night of the preconvention trip, October 12. Governor Holt of West Virginia welcomed the 160 geologists and friends. Two papers were read.

J. E. Billingsley (read by W. O. Ziebold), "Early Drilling Operations in West Virginia"
Paul A. Price, "The Anticlinal Theory and Later Developments in West Virginia"

MID-YEAR MEETING, PITTSBURGH, RESOLUTIONS COMMITTEE REPORT

Be it resolved, that we, members of The American Association of Petroleum Geologists, express our thanks to all who have contributed to the success of the 1937 mid-year meeting of the Association in Pittsburgh, and our appreciation of the unusual hospitality which has been tendered to us. Our thanks are due especially to the following individuals and organizations.

The wives of the local geologists and the Ladies Entertainment Committee, headed by Mrs. J. French Robinson.

The Engineers Society of Western Pennsylvania, and the Gulf Oil Corporation, both of which have contributed largely to the success of the meeting and the enjoyment of our visit.

The Honorable Homer A. Holt, Governor of West Virginia, who personally extended the hospitality of his State.

The Appalachian Geological Society of Charleston, West Virginia, which was chiefly responsible for the unusually interesting field trip through the Appalachian area.

The State Geological Surveys of the States of Virginia, West Virginia, and Pennsylvania, which made the field trips in their states of particular interest.

George H. Ashley, State geologist of Pennsylvania, Wilbur H. Stout, State geologist of Ohio, and C. A. Hartnagel of the New York State Museum, for their part in the technical program.

The Jones and Laughlin Steel Corporation, for the interesting trip through its plant at Aliquippa, Pennsylvania.

The Conventions Bureau of Pittsburgh, for many courtesies.

The William Penn Hotel, for its efficient service and hearty coöperation.

The Bureau of Public Safety of the City of Pittsburgh and the State Highway Patrols of the States of Maryland, Virginia, West Virginia, and Pennsylvania for their efficient handling of the traffic problems in connection with the various trips.

The H. J. Heinz Company, which entertained the ladies with a luncheon and a trip through its plant.

The many other individuals and corporations in the city of Pittsburgh, who contributed to the success of our meeting.

Be it resolved, that these resolutions be included in the minutes of this meeting and that copies be sent to the individuals and organizations named.

Ed. W. Owen, *chairman*
Thornton Davis
B. E. Thompson

Pittsburgh, Pennsylvania
October 16, 1937

PACIFIC SECTION FOURTEENTH ANNUAL MEETING LOS ANGELES, NOVEMBER 4–5, 1937

The fourteenth annual meeting of the Pacific Section of the Association was opened by Harry R. Johnson, president of the Section, in the Auditorium of the Edison Building, November 4. The morning and afternoon sessions of both days included a technical program of thirteen papers arranged by pro-

gram chairman Herschel L. Driver. The evening sessions included a dinner at the Clark Hotel, on Thursday, and a dinner-dance at the Biltmore Hotel Rendezvous, on Friday.

The total registered attendance was 238. One hundred seventy-five attended the annual business meeting of the Section. New officers for 1938 are: president, W. S. W. Kew, Standard Oil Company, Los Angeles; secretary-treasurer, E. Wayne Galliher, 1931 Myrtle Street, Bakersfield. The outgoing officers are: president, Harry R. Johnson; secretary-treasurer, James C. Kimble.

The Pacific Section of the Society of Economic Paleontologists and Mineralogists, under the chairmanship of Boris Laiming, held its annual meeting on the evening of November 4, at the Clark Hotel. The arrangements included a business meeting, dinner, and technical program.

ABSTRACTS OF PACIFIC SECTION PAPERS

The papers and abstracts are numbered as on the printed program of the Pacific Section meeting, November 4 and 5, 1937.

1. Gerard Henny, Geosynclines, Comprehensive Series, and Peneplains (abstract).

This paper is not given by the writer with the intention of proclaiming new ideas. He has been, however, in close relationship with Professors Haug and Termier, who first defined the terms: geosyncline and comprehensive series. Sometimes these terms are misused by modern geologists and the writer wishes to make clear the exact meaning of these words.

2. F. M. Anderson, Synopsis of the Upper Cretaceous Deposits in California and Oregon (abstract).

These Upper Cretaceous deposits make up the Chico series. It is nowhere found in a single section, but on the whole aggregates 25,000 feet or more in thickness. It begins with a great unconformity and overlap in late Albian time, and embraces all the succeeding stages known in Europe, probably up to the highest. It is capable of stratigraphic subdivisions into the following groups: Gaines group, western Shasta County, embracing late Albian to Turonian, 5,300 feet; Panoche group, Diablo Range, Senonian, including Coniacian to Campanian, 14,700 feet; Moreno group, Diablo Range, 5,000 feet.

The Gaines group is well characterized faunally and lithologically in its type area. The Panoche group, including the Chico Creek and Los Gatos beds, has characteristic faunas in its upper one-third, but its lower and major part is barren. The Moreno group is faunally and lithologically divisible into Moreno beds below, and Garas beds above, each with characteristic faunas.

3. Bruce L. Clark, Faulting or Folding in the Coast Ranges of California, Which? (abstract).

This paper deals largely with the discussion of the structures of the Coalinga area and makes a few references to the other areas to the south of that region, as for instance, the area to the north of Santa Ynez Mountains and the Ventura Basin. The purpose of the paper is to discuss the differences in interpretation and in data presented by Reed and Hollister in their book,

and those presented by B. L. Clark in his paper covering a portion of the same area.

The thesis of the paper is that faulting is the most fundamental structure in the Coast Ranges, and that folding is secondary to faulting.

4. A. J. Tieje, Geology and Oil Prospects of Victoria, Australia (abstract).

Victoria presents rocks of pre-Cambrian, Eopaleozoic (especially Ordovician), mid-Paleozoic, Kamilaroi, Triassic, Jurassic, Tertiary, and Quaternary age. Only the Tertiary (Upper Pliocene to Upper Oligocene (?) offers hope to the oil man. At Lake's Entrance (where interesting mud islands appear and disappear), glauconitic sandstone at about 1,400 feet depth carries small quantities of oil, either as an emulsion or by flotation on water. The beds dip southward off the coast on what may be a monocline; 50 miles to the west is the barren Baragwanath anticline, striking east and west and plunging east. The area between has not been drilled. The oil may derive from lepidocyclinid foraminifera, is very viscous, and yields no gasoline or kerosene fractions. The Austral Oil Company controls the chief area, various phases of geological work are subsidized, and no stock is sold. The Melbourne Street Railway absorbs all products.

5. G. B. Moody, California Earthquakes (abstract).

The more important California earthquakes and their effects on buildings are summarized.

6. G. M. Cunningham, Seismic Exploration of Difficult Areas (abstract)

Seismic exploration in California is favored by smooth terraine, good roads and pleasant climate. The purpose of this paper is to describe the difficult conditions being encountered in some of the other parts of the United States and in some tropical areas and what can be done to overcome them in seismic prospecting.

7. George L. Knox, The McDonald Island Gas Field (abstract).

The McDonald Island gas field is located on McDonald and Roberts islands, ten miles northwest of Stockton, California, in T. 2 N., R. 4 and 5 E., M.D.M. The islands are part of a general group in the delta area of the San Joaquin and Sacramento rivers. Both islands are practically at sea-level, with river waters excluded by means of levees.

There is no surface expression of the subsurface structure. The gas field was discovered as a result of a reflection seismograph survey carried out during the latter part of 1935. The first well, Standard Oil Company McDonald Island Farms No. 1 came in May 27, 1936, for 26,000,000 cubic feet of gas from a depth of 5,227 feet. Later drilling has checked the shape of the structure as postulated from seismograph work. Drilling has indicated an accentuation of structure with increasing depth and stratigraphic changes of importance. The productive gas zone is near the base of the Eocene.

8. Dean Sheldon, A Review of the Santa Maria Valley Oil Field (abstract).

A review of the history of the Santa Maria Valley oil field from its discovery on July 14, 1934, to date. The field has produced approximately 900,000 barrels of 16° gravity oil from 37 wells.

There are 36 active drilling projects in an area of 6¾ square miles.

All production is from the brown shale and sand of the Monterey formation (Middle Miocene) that overlies basement complex of questionable Franciscan age. The Sisquoc formation (Lower Pliocene?) and the Foxen formation (Upper Pliocene) in this area are nonproductive although they have some saturation.

Structurally the trap is a Sisquoc overlap of an eroded Monterey surface with indications that faulting will control to some extent the accumulation of oil in quantities of economic importance.

9. GLENN FERGUSON, Notes on the Extent of the Vedder Sand in San Joaquin Valley (abstract).

This paper presents evidence supporting the contention that the deeper sand cored in several wells on the floor of the San Joaquin Valley is the approximate stratigraphic equivalent of the Vedder sand.

10. R. G. REESE, El Segundo Oil Field, Los Angeles Basin, California (abstract).

This field was discovered in September, 1935. Development has been rather sporadic due to the uncertainties of obtaining commercial wells. Recent development has been greatly accelerated, however, by the completion of 3,000- to 4,000-barrel wells on the west side of the present proved area.

The oil occurs at the base of the sediments in porous rock between the Miocene shale and solid (Franciscan?) schist. Both the basal conglomerate and the underlying schist, where fractured or weathered, act as a reservoir. The structure is essentially a schist "high," overlapped by Upper Miocene sediments. Some cross sections and maps will be presented to show the structure and geologic history of the lower part of the sediments.

11. READ WINTERBURN, Wilmington Oil Field (abstract).

Approximately 270 wells have been completed in the Wilmington field since December, 1936. Production is obtained from Lower Pliocene and Miocene sediments. Structure, defined only in Los Angeles City, is a northwest-southeast anticlinal nose, plunging to the northwest, and cut by two main faults which have considerable effect on accumulation. Subsurface study indicates that folding and faulting occurred simultaneously with the deposition of Repetto beds. No movement has taken place since deposition of upper Pico beds, which rest unconformably on the Repetto.

12. FRANCIS P. SHEPARD, Sediments Off the California Coast (abstract).

On the shallow shelves off the California coast, recent sediments are thought to constitute only a thin and discontinuous mantle. Much of the bottom material appears to be related to earlier environments. On the other hand, sediments are being contributed largely by rivers and also by the waves to an extent that is probably much greater than is true of the east coast. Reasons will be given for believing that most of the sediment by-passes the shelf and is deposited either in the basins beyond or on the deep ocean floor. Coarser grades are formed into beaches and much of the sand is returned to the lands by the wind. The relation of various environments to bottom character will be discussed and also some description given of the new devices to be used at the Scripps Institution in studying sedimentation off this coast.

13. E. WAYNE GALLIHER, Geological Significance of the Glauconite Group (abstract).

A discussion of the occurrence of glauconite in older sediments and its relationship to biotite, vermiculite, and nontronite.

FRANCIS P. SHEPARD, Biological and Possible Economic Significance of Large Pleistocene Changes of Sea-Level (abstract; paper given before the Pacific section of Economic Paleontologists and Mineralogists).

Physiographic and biologic evidence suggests a lowering of sea-level during the Pleistocene, resulting in increase in salinity, elimination of shallow shelf areas, and exposure of oceanic margins to sub-aerial erosion. Pleistocene ice caps may have been large enough to reduce sea-level to the extent demanded. Some discussion of faunal changes and their possible relation to this lowering will be given. Also certain consequences of the lowering which appear to be related to petroleum exploration will be considered.

SOUTH TEXAS SECTION NINTH ANNUAL MID-YEAR MEETING, SAN ANTONIO, NOVEMBER 5-7, 1937

The South Texas Section of the Association met in ninth annual mid-year meeting and field trip, Friday, November 5 at San Antonio. Headquarters for registration, field trips, technical sessions, and entertainment was the Plaza Hotel. Charles Daubert was chairman of transportation for the local trips of interest; L. B. Snider was chairman of the field trips committee, Willis Storm was chairman of the technical program, and Phillip S. Shoeneck was chairman of the entertainment committee. The theme of the meeting was Cretaceous production. Local geologists were assigned as guides to San Pedro Park, Leon Springs, Helotes, and Medina County. It was possible on these trips to see nearly the entire Cretaceous section. The field itinerary included a visit to the Luling-Branyon producing field in Caldwell County.

The program on Saturday was opened with an address by H. B. Fuqua, president of the Association. Techincal papers were in the following.

ROBERT H. CUYLER, "Travis Peak Formation of Central Texas"
O. R. CHAMPION, "Subsurface Cross Section of Cretaceous Formations of South Texas"
LEAVITT CORNING, JR., "Igneous Activity in Cretaceous Formations of South Texas"
JOSEPH M. DAWSON, "Fault Line Fields of South Texas"
F. M. GETZENDANER and HENRY MCCALLUM, "Origin of Cretaceous Oils in South Texas"
FRED B. PLUMMER, "Results of Acidization and Shooting of Cretaceous Producing Formations"
WILLIAM CURRY, "Surface Cretaceous Formations of Edwards Plateau"

While primarily a field-trip meeting, social features were not overlooked. Mainly through the efforts of Mrs. Adolph Dovre a bridge luncheon for the ladies was held at the Plaza Hotel Friday afternoon.

On Saturday evening the annual dinner-dance, with an entertaining floor show, was held in the Plaza Hotel.

Approximately 250 geologists, their wives, and guests attended the meeting.

Officers of the South Texas Geological Society are: president, Harry H. Nowlan; vice-president, W. A. Maley; secretary-treasurer, Stuart Mossom; members of executive committee, Adolph Dovre and C. C. Miller.

Log and map of the Cretaceous field trip along the Balcones Escarpment with paleontologic notes on the various outcrops are available at $1.00 a set. Address Stuart Mossom, 1704 Alamo National Bank Building, San Antonio, Texas.

ASSOCIATION COMMITTEES

EXECUTIVE COMMITTEE

H. B. FUQUA, *chairman*, Fort Worth, Texas
IRA H. CRAM, *secretary*, Tulsa, Oklahoma
RALPH D. REED, Los Angeles, California
C. L. MOODY, Shreveport, Louisiana
W. A. VER WIEBE, Wichita, Kansas

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WILLIAM A. BAKER (1939)
ORVAL L. BRACE (1939)
CARY P. BUTCHER (1939)
FREDERIC A. BUSH (1939)
C. G. CARLSON (1938)
HAROLD S. CAVE (1939)
ROBERT W. CLARK (1939)
IRA H. CRAM (1938)
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A. ARTHUR CURTICE (1939)
A. R. DENISON (1939)
J. BRIAN EBY (1938)
H. B. FUQUA (1939)
BENJAMIN F. HAKE (1939)
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V. G. HILL (1939)
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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 12 (DECEMBER, 1937), P. 1617

Memorial

CHARLES ALBERT CHENEY

Charles Albert Cheney, consulting geologist and independent operator, was killed in an automobile accident near Mattoon, Illinois, on September 2, 1937. He was born in Madison, Wisconsin, in 1885, He is survived by his wife, Mildred H. Lustfield Cheney, to whom he was married on June 30, 1919, in New York City. Mrs. Cheney who resides at their home at 246 West Thirteenth Street, Tulsa, Oklahoma, was also painfully injured in the accident.

Cheney attended the University of Wisconsin from 1904 to 1909 and graduated with a Bachelor of Science degree. After graduation he worked as a field geologist for the Northern Pacific Railway at Cuyuna Iron Range, Minnesota, until 1910 at which time be became associated with the E. J. Longyear Company at Minneapolis. In 1913 Cheney became connected with C. K. Leith of Madison, Wisconsin, noted geologist and iron-mining expert, with whom he worked until 1915 at which time he became chief geologist and superintendent of drills for the George H. Crosby interests in Wisconsin, Minnesota, and Michigan with headquarters at Duluth, Minnesota.

In 1918 he moved to Tulsa, Oklahoma, as geologist for the M. M. Valerius Oil Company for whom he devoted his time in surface and subsurface studies of the entire Mid-Continent area and especially western Kansas where he achieved early recognition as an authority on the then little known subsurface features of that area.

Since 1920, Cheney maintained offices in Tulsa for his consulting work and drilling operations which centered chiefly in Oklahoma and Kansas. At the time of his death he had been chief consultant for J. H. Leavell, Tulsa, advising on coal and oil properties which extended from Texas to Kansas. He was also a vice-president and director of the M. M. Valerius Royalty Corporation. He was a member of The American Association of Petroleum Geologists, the American Institute of Mining and Metallurgical Engineers, and the Tulsa Geological Society.

Cheney contributed a number of articles to geological literature: "What the Dip Needle Can and Cannot Do"; "Structure of the Cuyuna Iron Range of Minnesota"; "Use of the Aneroid Barometer in Geologic Mapping in Petroleum Areas"; "Petroleum in Colbert County, Alabama"; and "Salt Domes of Northeastern Texas."

Cheney was very widely known in the Mid-Continent as a man of unquestioned integrity and his ability as a petroleum geologist was respected and admired by all geologists and operators. His pleasant personality, good humor, and willingness to give information from his extensive store of geological data made him liked and admired by all who knew him. His death came as a great shock to his host of friends and past and present business associates who feel they have lost a true friend as well as a business adviser.

M. M. VALERIUS

TULSA, OKLAHOMA
October 16, 1937

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 12 (DECEMBER, 1937), PP. 1618-1620

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

ELIOT BLACKWELDER, of Stanford University, California, has resumed his work at the university after a sabbatical year in Europe and Egypt.

WALLACE E. PRATT, director of the Standard Oil Company of New Jersey, was presented with a distinguished service award by the Texas Division of the Mid-Continent Oil and Gas Association.

CHARLES P. MCGAHA, of the Fain-McGaha Oil Corporation, Wichita Falls, Texas, has been elected president of the Texas Division of the Mid-Continent Oil and Gas Association.

H. F. MOSES, superintendent of the eastern division of the Carter Oil Company, at Mattoon, Illinois, has been transferred to Tulsa to assist vice-president McCollum in the geological, geophysical, and scouting divisions.

ALBERT HEIM, formerly director of the Geological Museum and Swiss Geological Survey, Zurich, died on September 5 at the age of sixty-eight.

WILLIAM J. MILLARD may be addressed at the Army and Navy Club, Manila, Philippines.

The fiftieth annual meeting of the Geological Society of America will be held on December 28–30 under the auspices of the Geological Society of Washington at the Hotel Washington, Washington, D. C. Concurrent meetings are the twenty-ninth annual meeting of the Paleontological Society, the eighteenth annual meeting of the Mineralogical Society of America, and the seventeenth annual meeting of the Society of Economic Geologists.

BAILEY WILLIS has returned to Stanford University, California, after a year of studying mountain-building during the Tertiary and Pleistocene in India, the East Indies, the Philippines, and Japan.

The South Louisiana Geological Society held its regular monthly meeting at the Majestic Hotel, Lake Charles, October 18. GEORGE S. BUCHANAN, of the Adams Louisiana Corporation gave a paper on "The Cheneyville Oil Field, Rapides Parish, Louisiana, and Its Relation to Areas of Mother Salt Deposition."

H. W. STRALEY, III, of the Department of Geology, University of North Carolina, Chapel Hill, has returned to the university after a field season spent in South Carolina, where he and W. F. PROUTY, of the same department, were studying the genesis of the "Carolina Bays."

C. S. CORBETT has entered the employ of the Socony-Vacuum Oil Company, Inc., as geologist in the producing department. His address is 26 Broadway, Room 1135, New York City.

T. R. BANKS is geologist with the Transwestern Oil Company, Milam Building, San Antonio, Texas.

At a meeting of the West Texas Geological Society held at Midland, October 27, the following paper was given by D. D. UTTERBACK: "Porosity of Limestone Reefs."

RICHARD T. SHORT, formerly of San Antonio, Texas, is now geologist for the Navarro Oil Company, Box 138, Alice, Texas.

W. P. SALAS, formerly with Seismograph Service Corporation, Tulsa, is now with the Carter Oil Company, Wichita, Kansas.

R. C. POWLESS has been named scout in the geological department for Tide Water Associated Oil Company for the Southwest Texas district with headquarters at San Antonio. He was formerly in the Tulsa offices of the company.

GLENN GRIMES, consulting geologist of Oklahoma City, was the principal speaker at a meeting of the Oklahoma City Geological Society, November 8. His subject was "Geology of the Tatums Field in Carter County—with Notes on Deep Drilling at Fox."

R. A. SHELDON has changed his address from San Antonio, Texas, to the Tropical Oil Company, Geological Department, Barranca-Bermeja, Colombia, South America.

Mr. and Mrs. CHALMER J. ROY announce the arrival of David Chalmer Roy, born November 14, at Baton Rouge, Louisiana. Roy is instructor in the department of geology at Louisiana State University.

JOHN M. LOVEJOY, president of the Seaboard Oil Company of Delaware, recently received the degree of doctor of science from Colby College, Waterville, Maine.

E. H. FINCH, geologist of San Antonio, Texas, recently sailed from New York for Angola, West Africa, to do geological work for a West African company.

ROY T. HAZZARD and B. W. BLANPIED, geologists for the Gulf Oil Corporation, Shreveport, Louisiana, presented a paper, "Occurrence of Chickasawhay and Vicksburg in Wayne County, Mississippi," before the regular monthly meeting of the South Louisiana Geological Society, Lake Charles, on November 15.

THOMAS S. COX, district geologist for the Plymouth Oil Company with headquarters at Texon, Texas, has resigned to engage in consulting work. His office is in San Angelo, Texas.

At a meeting of the Tulsa Geological Society on November 15, Messrs. DELLENEY and STEWARD, of the Schlumberger Well Surveying Corporation, Oklahoma City, spoke on "Location of Water-flows and Gas-oil Contact."

CHESTER W. WASHBURNE has returned from field work in Venezuela. He has moved his office from 149 Broadway to 50 Church Street, New York City, where he will handle also the consulting work of FREDERICK G. CLAPP during the absence of Mr. Clapp in the Near East.

JOHN S. IVY, chief geologist, United Gas Company, spoke on the "Rodessa Oil Field" and WAYNE V. JONES, geologist, Tide Water Oil Company, read a paper on the Cayuga oil field at recent meetings of the Dallas Petroleum Geologists.

The Texas Academy of Science held a joint luncheon with the Dallas Petroleum Geologists, November 12, at the Baker Hotel, Dallas. Speakers at the luncheon were: CHARLES GILL MORGAN, geologist, who discussed his experiences with the second Byrd Expedition, and J. ELMER THOMAS, Fort Worth, who discussed his recent trip to the International Geological Congress at Moscow. At the scheduled sessions of the Academy, papers were read by ROBERT T. HILL, NORMAN L. THOMAS, F. B. PLUMMER, H. P. BYBEE, JOHN EMERY ADAMS, and F. M. GETZENDANER. DOUGLAS R. SEMMES, vice-president, Texas Academy of Science, presided.

R. W. CLARK, Appalachian District Representative of the Association, and general chairman of arrangements for the mid-year meeting held at Pittsburgh in October, announces that the field trips committee had a balance of $135.00 after paying all bills connected with the trips. After canvassing the membership in the Appalachian District and also the members of the executive committee of the A.A.P.G. the money has been placed in the hands of M. G. GULLEY, R. E. SHERRILL, and PAUL H. PRICE, as trustees, to be expended at their discretion. The money has been placed in the bank on interest, to be used when a proper candidate is available. The money may be spent on a graduate student working on an acceptable problem in any institution of learning. The committee desires to receive applications from graduate students whom this amount of money would help to continue their investigations. The student should be recommended by the head of the department in the institution in which he expects to do his graduate work and recommendations from his past professors would also be helpful. He should state the problem on which he expects to work and the school at which the work would be done. Decision as to the ultimate disposition of the money along these lines rests entirely with the committee. Applications should be mailed to M. G. GULLEY, Box 1166, Pittsburgh, Pennsylvania.

At a meeting held November 4, 1937, the following officers were elected by the East Texas Geological Society, Tyler, Texas, for the new fiscal year: president, ROBERT L. JONES, Empire Oil and Gas Company; vice-president, C. L. WRIGHT, Shell Petroleum Corporation; and secretary-treasurer, E. A. MURCHISON, JR., Humble Oil and Refining Company. GEORGE PIRTLE and CHARLES HOOKWAY were elected as members of the executive committee. W. A. GORMAN related his experiences while mapping geology over a period of 3 years in Northern Rhodesia, South Africa.

ROBERT MITCHELL, district geologist for the Stanolind Oil and Gas Company at Tyler, is being transferred to Houston, where he will be connected with the company's geophysical department. A. A. HOLSTON will be district geologist at Tyler.

The Eleventh National Convention of Sigma Gamma Epsilon will be held at the University of Texas on December 30–31, 1937. All old members are cordially invited to attend. Detailed information may be obtained by addressing the general secretary of Zeta Chapter, Geology Department, University of Texas, Austin, Texas.

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BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

VOLUME 21
JANUARY—DECEMBER 1937
PART I
PAGES 1-832

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BOX 979, TULSA, OKLAHOMA

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PUBLISHED
MONTHLY

Composed and Printed by
George Banta Publishing Company
Menasha, Wisconsin, U.S.A.

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ERRATA

Page 247, Figure 1: the word ELDORADO in the upper part of the map should be EUREKA.

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BULLETIN

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AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

VOLUME 21

JANUARY—DECEMBER 1937

PART II

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ERRATA

Pages 1137–38: the word "Congollo," appearing in several places on these pages, should be *Cogolla*.

Page 1271, Table I, column 3 under Avery Island: "7.90" should be 0.790.

Page 1285, line 2 from bottom: "$\overline{01\bar{1}1}$" should be $\overline{10\bar{1}1}$; and "$\overline{01\bar{1}2}$" should be $\overline{01\bar{1}1}$.

Page 1293, line 3 from bottom: the word "borosilicate" should be *borate*.

Page 1316, line 8: the last four words should be *too persistently large to*.

Page 1449, Fig. 2: the scale "1:1000000" should be removed.

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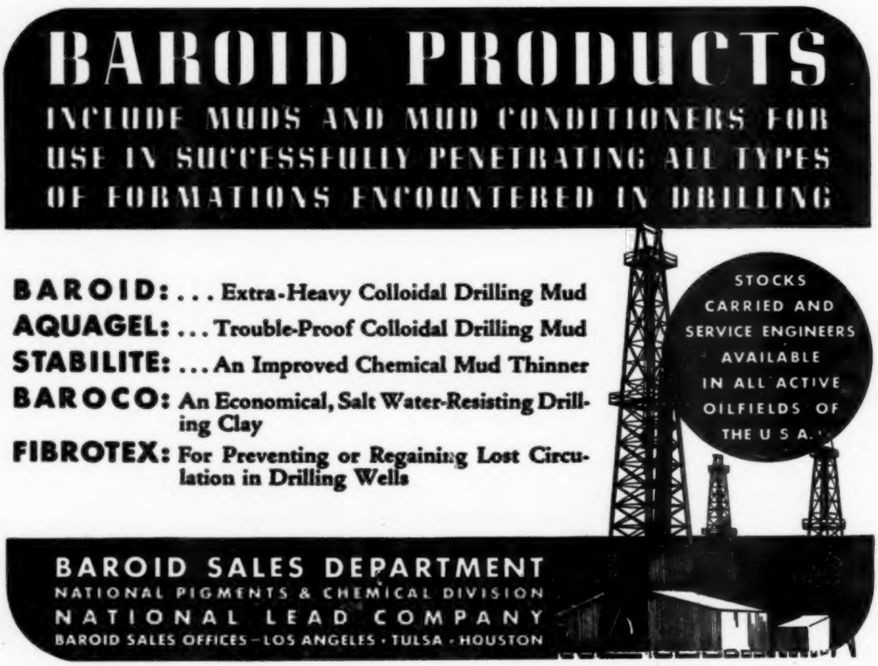
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